SECURITY CLASSIFICATION OF THIS PAGE

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REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
	3. DISTRIBUTION/AVAILABILITY OF REPORT APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED
	5. MONITORING ORGANIZATION REPORT NUMBER(S) DTRC - SSID - CR - 6 - 89
6a. NAME OF PERFORMING ORGANIZATION REXROTH CORP. / 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION DAVID TAYLOR RESEARCH CENTER
6c. ADDRESS (City, State, and ZIP Code) 2315 City Line Road Bethlehem, PA 18017	7b. ADDRESS (City, State, and ZIP Code) Code 1240 Bethesda, MD 20084-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION DAVID TAYLOR RESEARCH CENTER / 8b. OFFICE SYMBOL (If applicable) 1240	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00167 86 C 0098
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO.
62744N	CF44455		DN978568

11. TITLE (Include Security Classification)
INSTALLATION AND TEST OF A HYDROSTATIC DRIVE TRANSMISSION IN A GOVERNMENT FURNISHED M-113 VEHICLE

12. PERSONAL AUTHOR(S)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
FINAL	FROM 7/86 TO 11/86	1986 November 10	153

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Military Vehicles, Brakes, Gears, Transmission, Hydrostatic Drive, Heating and cooling, Clutch, performance (engineering), Service Life. (JES)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A design effort was performed to install a Hydrostatic Drive Train with secondary regulation (constant pressure) in a 14 ton Military Tracked Vehicle. The system offered simplified control and utilizes a single variable displacement pump driven by the engine controlling the displacement, speed, and torque of hydraulic drive motors. Two speed final drives are required between the motors and track sprocket. Vehicle requirements and expected performance are presented.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Michael Gallagher	22b. TELEPHONE (Include Area Code) (301) 227-1852 / 22c. OFFICE SYMBOL 1240

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

DAVID TAYLOR NAVAL SHIP R & D CENTER

Contract No. N00167-86-C-0098

Installation and Test of a Hydrostatic Drive Transmission In a Government Furnished M-113 Vehicle

SYSTEM DESIGN REPORT

November 10, 1986

Prepared by

REXROTH CORPORATION
Bethlehem, PA

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Report No.

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1.0 Abstract

The design flexibility afforded by distributed drive train technology in combat vehicles is most evident in the context of hydrostatic drives when compared to more conventional cross drive transmissions. For an amphibious vehicle, weight distribution is a key factor that makes hydrostatic drives attractive to the designer; but in the past, poor efficiency, lack of inter-track torque transfer during powered turns and lack of control stability have forced further development prior to adoption.

The Rexroth Corporation Hydrostatic Drive with Secondary Regulation (HDSR) is a unique and inovative form of hydrostatic drive that addresses the shortcomings of conventional systems. Rexroth has analyzed the requirements for a 14 ton tracked vehicle (M113) and designed a transmission that will demonstrate the HDSR concepts to the full. The system is based on a single variable displacement pump controlling the displacement and thereby the speed and torque of the variable displacement drive motors. The system is designated constant pressure and hence the drive and control of auxiliary circuits is greatly simplified. The analysis of required vehicle performance characteristics, show that the HDSR transmission meets specified operating requirements. All assumptions in the analysis of efficiencies and performance are taken as "worst case" or are noted otherwise and are considered to be conservative.

The hydrostatic transmission system proposed for use in this report is the most efficient system commercially available today.

2.0 M113 Program Objective

The objective of this program is to equip a M113 Armored Personnel Carrier with a Rexroth hydrostatic drive system which will provide an effective and efficient means of transmitting power from the engine to the tracks of the vehicle. Rexroth will also equip the vehicle with control systems which will allow simple, logical automotive type operation of the vehicle with a minimum of operator skill and/or training. Rexroth will further equip the vehicle with all auxiliary equipment (such as cooling fan drive) as required to support main systems. Rexroth will install, test and adjust all systems for proper operation, after which the vehicle will be made available for testing and evaluation by the U.S. Marine Corps.

All systems are being designed with consideration givento the following criteria:

- Human Factors Engineering (HFE)
- Accessibility and maintainability of HDSR component
- System integration - M113/HDSR

3.0 M113 Main Systems Required

Hydrostatic Drive with Secondary Regulation (HDSR)

Electronic control for HDSR system.

Electronic vehicle control system.

Two-speed, power-shift final drive gear units.

3-pad pump drive gear box.

Hydrostatic cooling fan drive.

Auxiliary hydraulic circuit to cool gear drives, shift gears, release brakes and operate the ramp.

These systems are defined in further detail in subsequent portions of this report.

4.0 M113 HDSR System Description

4.1 General

Hydrostatic Drives with Secondary Regulation (HDSR), as defined by The Rexroth Corporation, incorporate variable displacement (over center) hydraulic motors connected in parallel circuit. In theory, the systems operate at constant pressure with motor displacements being varied to meet motor speed requirements and assumes that sufficient flow and torque is available to allow the system to function. In HDSR systems, the motors also control forward and reverse directions of rotation which allows counter rotation turns on tracked vehicles and controls vehicle direction. Successful operation of HDSR systems is keyed to accurate and high speed motor displacement control. In HDSR systems, as many motors may be used as are required to satisfy system (vehicle) requirements and all motors may be controlled independently.

4.2 HDSR Applications

HDSR Systems are most effectively applied in applications where loads are both being driven and are, in other operating modes, driving back into the system. In HDSR systems where motor loads are (in some operating modes) driving the system, this energy is directly additive to prime mover (engine) power to drive other motors. This is the principle advantage of HDSR over conventional hydrostatic drive systems.

M113 propulsion is a good application for HDSR where energies generated by the inside track in the execution of powered turns are directly additive to engine power to meet increased power demand of the outside track.

Rexroth is a world leader in hydrostatic drive technology. Experience to date has been primarily with conventional systems in a wide range of applications. Rexroth experience indicates that vehicle operating requirements of the M113 APC approach the technical limits of conventional hydrostatic drive systems. It is felt that advantages offered by HDSR will extend the operating range over conventional systems and have therefore selected this system (HDSR) as being proper for M113 main propulsion.

4.3 HDSR Rationale

4.3.1 Direct regeneration of energy generated by the inside track mechanism to the outside track mechanism in the execution of powered turns. Energy losses are limited to efficiency losses in the track motor and drive mechanisms.

4.3.2 Better motor control required by HDSR systems will result in superior vehicle mobile control as compared to conventional closed loop hydrostatic drives. This should be most apparent at higher vehicle speeds where either straight line or minor adjustments to straight line operation are required.

4.3.3 Energy storage capability option may prove useful to meet peak energy demands. Some HDSR Systems store braking and/or overrunning load energies in hydraulic accumulators for later use to improve fuel consumption or provide added energy for acceleration. At Rexroth's discretion, benefits of this feature may benefits of this feature may be explored.

4.4 HDSR Main Component Description

The specific circuit which has been designed for this project (Attachment 4) incorporates Rexroth model AA4V mobile motors and pump. These units are described as axial piston, over center, swash-plate design. They are capable of operating at pressures of up to 6000 psig

and were selected for this application on the basis of proven reliability in hydrostatic drives systems and many available control options (Attachments 1 & 2).

The HDSR main pump will be a Rexroth model AA4V250 (15.25 cu-in/rev.) axial piston pump with DA (Automotive) Control. This pump was designed specifically for hydrostatic drive systems and is widely used in heavy duty applications. The DA control is selected as it automatically maintains selected engine speed regardless of vehicle power demands. This pump and the DA control are described in detail in Attachment 1 data booklets RA06202 and RA06210/7.86. A single pump will drive the HDSR system.

Motors selected for this system are Rexroth AA4V125EL (7.625 cu-in/rev) pumps which may be used as motors as well as pumps. Motor control is electronic proportional for speed and accuracy of motor displacement adjustment. Two motors per track are specified in order to allow motor operating speeds of up to 3000 rpm. These motors are light weight mobile models. For additional detail, see Attachment 2 (RA06200).

4.5 The Constant Pressure System

Main system pressure is controlled with a Rexroth model DBETR (electronically controlled) pressure relief valve. HDSR systems are defined as "constant pressure" systems. Operating

pressure in this circuit will be adjusted to optimize overall system performance and meet peak system demands. With this control feature, our system may be defined as a "constant pressure" system with adjustable pressure levels. For additional details see Attachment 3 (RE 29166/8.86).

4.6 Main System Auxiliary Components

The system circuit diagram (with bill of material) is shown in Attachment 4. In this circuit, the main pump (Item 1.0) drives four (4) motors which are connected in parallel (Items 2.0). The circuit may be described as a modified open loop system in that for all driven modes of operation, fluid flow is always in the same direction. The open loop description is modified in that return lines are connected to the pump inlet which closes the loop. For braking modes of operation, fluid flow is reversed.

System pressure is adjusted with a model DBETR (electronically controlled) relief valve (Item 3.0).

Accumulators (Items 5 & 6) are shown connected in both pressure and return line. These are for system pressure stability and to prevent pump or motor cavitation during displacement adjustments.

Motor control fluid pressure is set at 350 psi by a pressure reducing valve (Item *) and filtered through a nominal 10 micron filter to ensure control reliability. Motor control pressure and flow is stabilized with accumulators (Items 7.0).

System cooling and filtration are accomplished in the loop which returns control flow from the main pump and four motors to tank. The air to hydraulic heat exchanger (Item 9.0) which was GFE supplied with the vehicle will be used to cool this system. Filtration is addressed in Attachment 13.

The hydraulic reservoir (Item 12.0) also supplied with the vehicle will be used for this system. This is a simple circuit. All components are standard production items with proven performance and reliability.

The unique feature of the system is in the control which is discussed in the electronic control section of this report.

4.7 Performance Predictions

4.7.1 To achieve 60% gradability, 8400 lb-ft of torque must be delivered to each of the vehicle sprockets. In this operating mode, motor displacements are maximum (7.63 cu-in/rev) and pump displacement is limited by the DA control to maintain engine peak power of 300 BHP at 2800 rpm.

<u>System operating parameters in this mode are:</u>

Engine speed = 2800 rpm

Pump speed = 2500 rpm @ 1.12:1 gear reduction

Engine output = 300 bhp

Parasitic losses = 46 hp (Fan)

15 hp (Pump drives)

2 hp (Aux. pump)

68 hp (HDSR losses including line & F.D. losses)

Net hp available = 169 hp to sprockets

Max. sprocket rpm = $\dfrac{(169\ \text{hp})\ (63000)}{(100{,}800\ \text{in-lb})\ (2\ \text{sp.})}$ = 52.7 rpm (3.0 mph)

System flow = 52.7 rpm $\dfrac{(8)\ (7.63\ \text{cu-in/rev.})\ (4\ \text{Motors})}{.86\ (\text{Eff})}$

= 14,962 cu-in/min (64.8 gpm)

Pump displacement = $\dfrac{14{,}962\ \text{cu-in/min}}{(2500\ \text{rpm})\ (.91)}$ = 6.60 cu-in/rev (43% stroke)

Operating pressure = 5800 psi

4.7.2 To achieve 40 mph vehicle speed, the pump is at full displacement (15.25 cu-in/rev), motors are destroked to meet speed requirements and system pressure is reduced to improve efficiency.

<u>Operating parameters for this mode are:</u>

Engine speed = 2800 rpm

Pump speed = 2500 rpm @ 1.12:1 gear reduction

Sprocket speed = 700 rpm @ 40 mph

Motor speed = 3000 rpm @ 4.28:1 gear reduction

System flow = (2500 rpm) (15.25 cu-in/rev) (.94)

= 35,837 cu-in/min (155 gpm)

Motor displacement $= \dfrac{(35{,}837 \text{ cu-in/min})\ (.88)}{(3000 \text{ rpm})\ (4)} = 2.63$ cu-in/rev/motor (34% stroke)

Sprocket torque = 8750 lb-in/sprocket @ 125 lb/ton roll. res.

Motor torque $= \dfrac{8750 \text{ lb-in}}{(4.28)\ (2)\ (.93)} = 1{,}100$ lb-in/motor

Motor pressure $= \dfrac{1100\ (2)}{(2.63)\ (.93)} = 2{,}825$ psi

1.5 A

Sprocket hp $= \dfrac{TN}{63{,}000} = \dfrac{(8750 \text{ lb-in})\ (2)\ (700) \text{ rpm}}{63{,}000} = 194.4$ hp

Pump hp $= \dfrac{PQ}{1714} = \dfrac{(2825 \text{ psi})\ (155 \text{ gpm})}{1713} = 255$ hp (input)

Main cooling fan must operate at less than 5000 rpm 28 hp is available for fan operation in this mode.

4.7.3 Acceleration

In normal vehicle operation, gear shifting will take place in the 10-12 mph range in order to effect a smooth torque transfer at a constant system pressure. This is shown graphically on the torgue speed curve in Attachment 6.

We do not plan to shift gears when evaluating HDSR system acceleration capability between 0-20 mph. 20 mph may be reached with motor speeds of 2800 rpm which is acceptable for AA4V125 high speed version motors. Average accelerations are used to calculate accelerations between points on the torque speed curve to determine estimated acceleration time.

Formulas for acceleration: $F = ma$

$V = V_o + at$

Acceleration Projection:

SPEED MPH	SPEED FT/SEC	SPROCKET TORQUE LB-FT	DBP LB	MASS LB/FT/SEC²	ACC FT/SEC²	TIME SEC.
3.0	4.40	8400	13,000	870	14.94	0.29
5.0	7.33	7200	11,000	870	12.64	0.23
7.5	11.00	5200	7,667	870	8.81	0.42
10.0	14.67	4100	5,833	870	6.70	0.55
15.0	22.00	2650	3,416	870	3.93	1.87
20.0	29.33	2250	2,750	870	3.16	2.32
						5.39

4.8 Summary of System Operating Parameters

	Low Speed High DBP	High Speed Low DBP
Engine speed	2800 rpm	2800 rpm
Pump speed	2500 rpm	2500 rpm
Motor(s) speed	568 rpm	3000 rpm
Vehicle DBP	17,660 lbs	1750 lbs
System flow	65 gpm	155 gpm
System press	5800 psi	2825 psi

Attachment 5 shows a graphic representation of projected sprocket torque vs. speed capability.

4.8.1 Critical Response Times

There are no critical response times with respect to components selected for application of the HDSR system in this vehicle. The slowest component in this system is the main pump which goes from zero to full stroke in less than 250 milliseconds. Motor response time to go from zero to full stroke is less than 150 milliseconds. On a 14 ton vehicle, these response times are more than adequate to provide a stable system.

4.8.1 Filtration (See attached sheet)

4.8.1.1 Filtration

Fluid filtration is a major design consideration in this vehicle. It must achieve and maintain proper fluid particle counts while also providing for easy serviceability, minimum system function interference, adequate warning modes and a "Fail to Safe" operation! Each of these design criteria are rationalized and discussed below. Please keep in mind the fact that this vehicle has (4) hydraulic systems utilizing two different fluids and two reservoirs.

Filtration Requirements:

The fluid should be filtered prior to system start-up, and continuously during operation, to achieve and maintain a cleanliness level of ISO 18/15. (This corresponds approximately to NAS 1638 Class 9, or SAE (1963) Class 6.) This recommendation is considered a minimum, as better cleanliness levels will significantly increase component life.

Serviceability:

All filter cannisters will be located in the vehicle passenger compartment near the bulkhead of the engine compartment. Here they may be directly accessed and serviced with standard commercial hand tools. If desireable they could be set up to allow "in-transit" servicing. Only two different design elements are required.

Circuit Placement:

Circuit placement addresses two design criteria; first to minimize the power required to push fluid across a filter element and secondly to reduce the components size and weight by avoiding high pressure and high flow requirements. The solution is to only filter the hot reservoir-return oils and the charge/control oil circuits. This

method is only adaptable to closed-loop type circuits and is reflected in our hydraulic circuit schematics.

Component Selection:

See Attachment 13.

The intended filters as specified in each system's Bill of Materials are manifold mounting types. They afford a no-fitting, no-hose system connection and thus protect against leakage, require less mounting hardware, are easier to service, and offer a cleaner installation. Each filter has built into it a bypass circuit to allow continued operation should a filter cartridge fail. This is the "Fail to Safe" mode.

Each filter possesses two early clogging/failure warning signals. The operator is warned via a red warning light at his station while a mechanical "pop-up" indicator is located at the filter.

4.8.2 Regeneration of Powered Turns

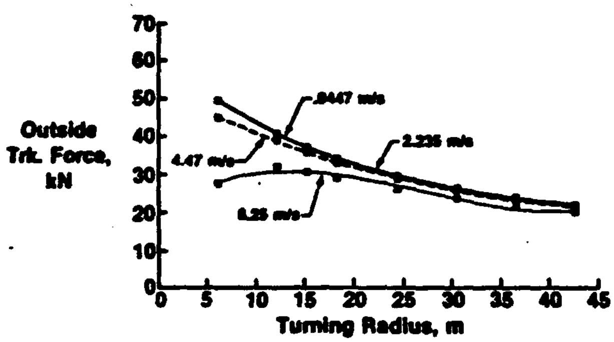
There will be speed and turning radius ranges where the inside track mechanism generates and inputs power to the HDSR system. This power transfer is estimated here.

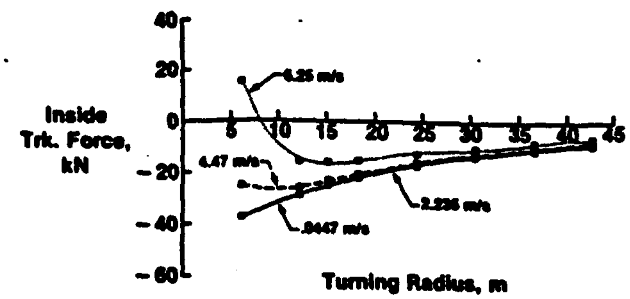
Power regeneration (or transfer) is a function of:

- Vehicle speed
- Vehicle trun radius
- Vehicle rolling resistance which is considered to be constant at 125 lb/vehicle T (62.5 lb/ton/track) in this estimate.

We are told that the M113 track mechanisms are configured such that the vehicle assumes a 200 ft. turning radius with one track in neutral on level ground. At a turning radius of 200 ft. it is reqsonable to assume that the inside track will not require power and that all available power may be directed to the outside track. Some benefits from power regeneration should then accrue from the inside track for some turn radii which are less than 200 ft.

Dr. M.K. Kar (John Deere) projects the relationship between inside and outside track forces in his paper on "Prediction of Track Forces in Skid-Steering of Military Tracked Vehicles", March 1984.





The following conclusions are drawn from these graphs:

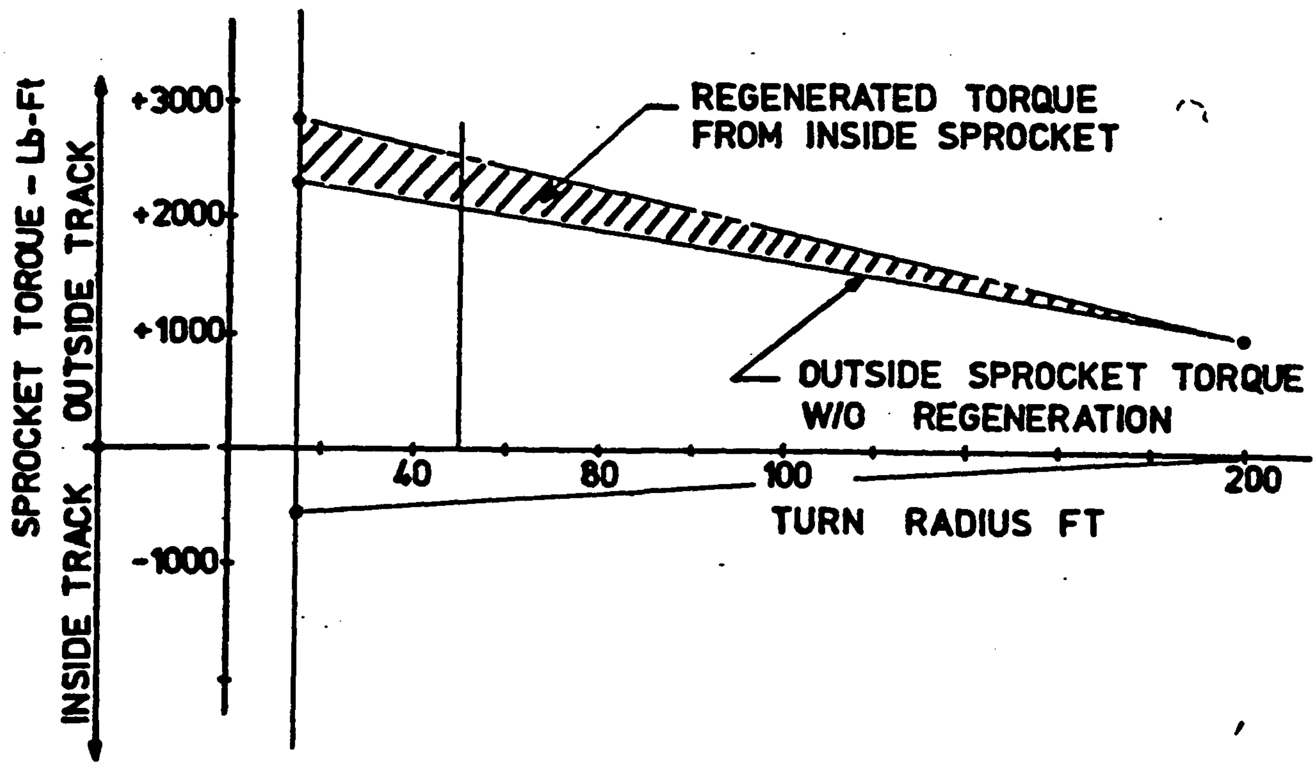
- Forces on the inside track are opposite of forces on the outside track and are regenerative. — opposite but not equal
- Force relationships become unstable at a turn radius of less than 15 m (49.2 ft) at speeds greater than 6.25 m/s (14 mph). At lower speeds systems are stable to turn radii of approximately 15 ft.
- Forces on the inner track are approximately 50% of the absolute force values on the outside track.

For the purpose of this estimate, it is assumed that these conclusions are valid.

In this estimate, "Track Force" is evaluated in terms of sprocket torque and assumes that all available engine power is transmitted in the form of torque to the outside track.

Relationships between applied power (torque), regenerative power (torque) and turn radii are considered to be linear.

Graphic representation of relationships:



Regenerative torque increases from zero at a turn radius of 200 ft to a maximum of 520 lb-ft at a turn radius of 15 ft which is minimum for this estimate.

Regenerative torques were calculated as being 50% of torques applied to the outer track less rolling resistance for one track.

Regenerative torque as a function of turn radius is expressed as follows:

$$T_R = 562 - 2.81\,R$$

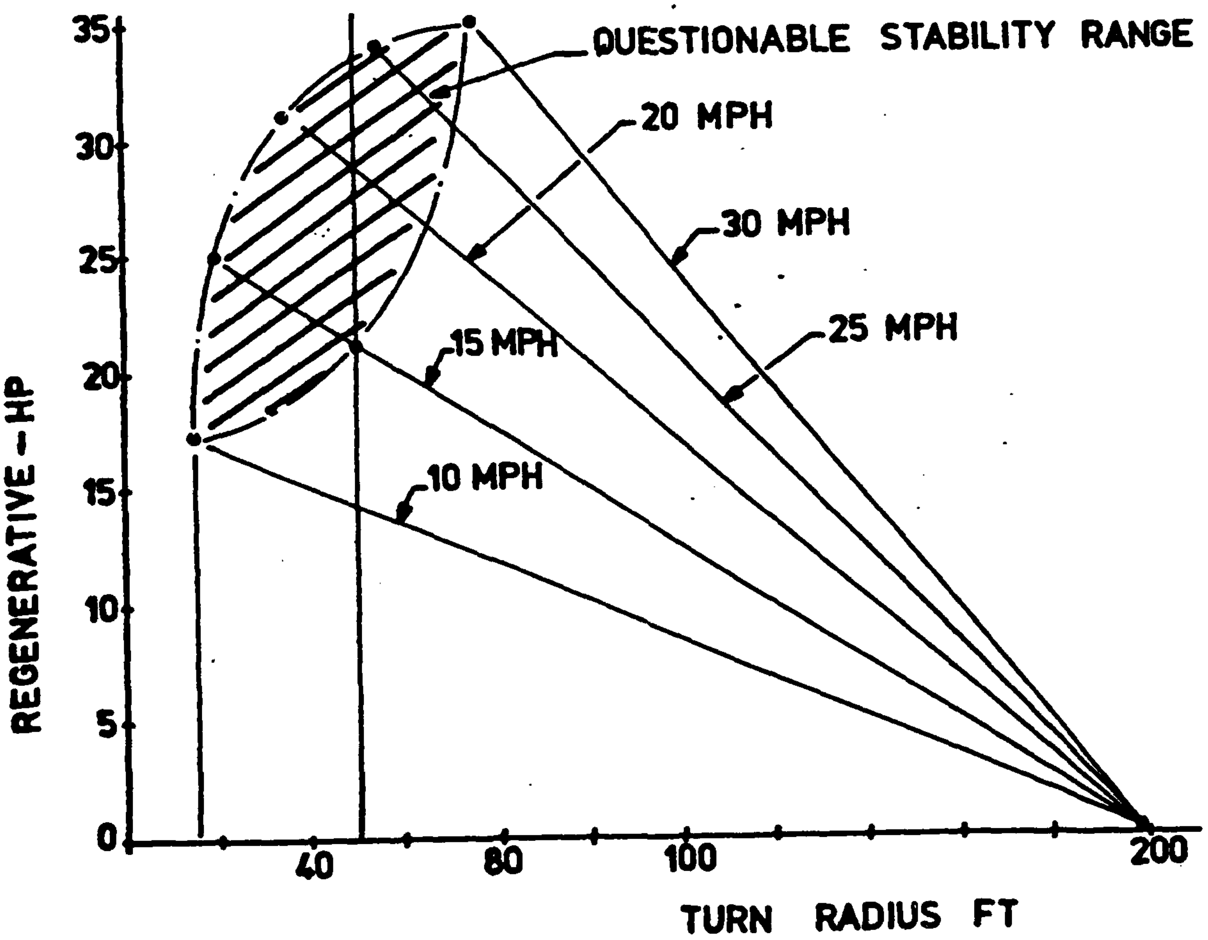
Where:

T_R = Torque (lb-ft)

R = Turn radius (ft)

Applying regenerative torques to vehicle speeds gives regenerative hp at various vehicle speeds.

In constructing the following graph it was assumed that turn radius vs. speed should never exceed a condition where lateral forces on the vehicle exceed 0.8g.



At vehicle speeds above 30 mph, limitations of turn radius decreases regeneration rapidly. For the purpose of this estimate, speed above 30 mph will be neglected.

From the efficiency analysis, it is estimated that average hp available for tractive effort is approximately 175. Regenerative power varies between 17.3 hp at 10 mph to 35 hp at 30 mph. This relates to power improvements of between 10 and 20% in the regenerative range.

Operating conditions will likely have an effect on regeneration. Displacement setting of the hydraulic motor on the inside track can further effect regeneration.

The purpose of this estimate is to establish the concept of positive regeneration of power in the execution of powered turns on military tracked vehicles. To quantify the level of regeneration conclusively will require vehicle testing.

Positive benefits do accrue from regeneration. Other HDSR systems have proven this concept.

The only question on this program is the actual level of regeneration.

4.9 Fluid Selection Rationale

Silogram M.P. grade 207 premium anti-wear hydraulic oil is selected for use in the HDSR main hydraulic system. This fluid is produced by A. Margolis and Sons.

The fluid is recommended on the basis that its flash point is higher than Mil-H-46170A which is classified as a "Fire Resistant" gluid.

Silogram M.P. grade 207 is recommended in preference to Mil-H-46170A on the basis of higher viscosities at equal temperatures.

The attached viscosity chart and specification sheet further detail these points.

Flash point for Mil-H-46170A is 424 degrees F.

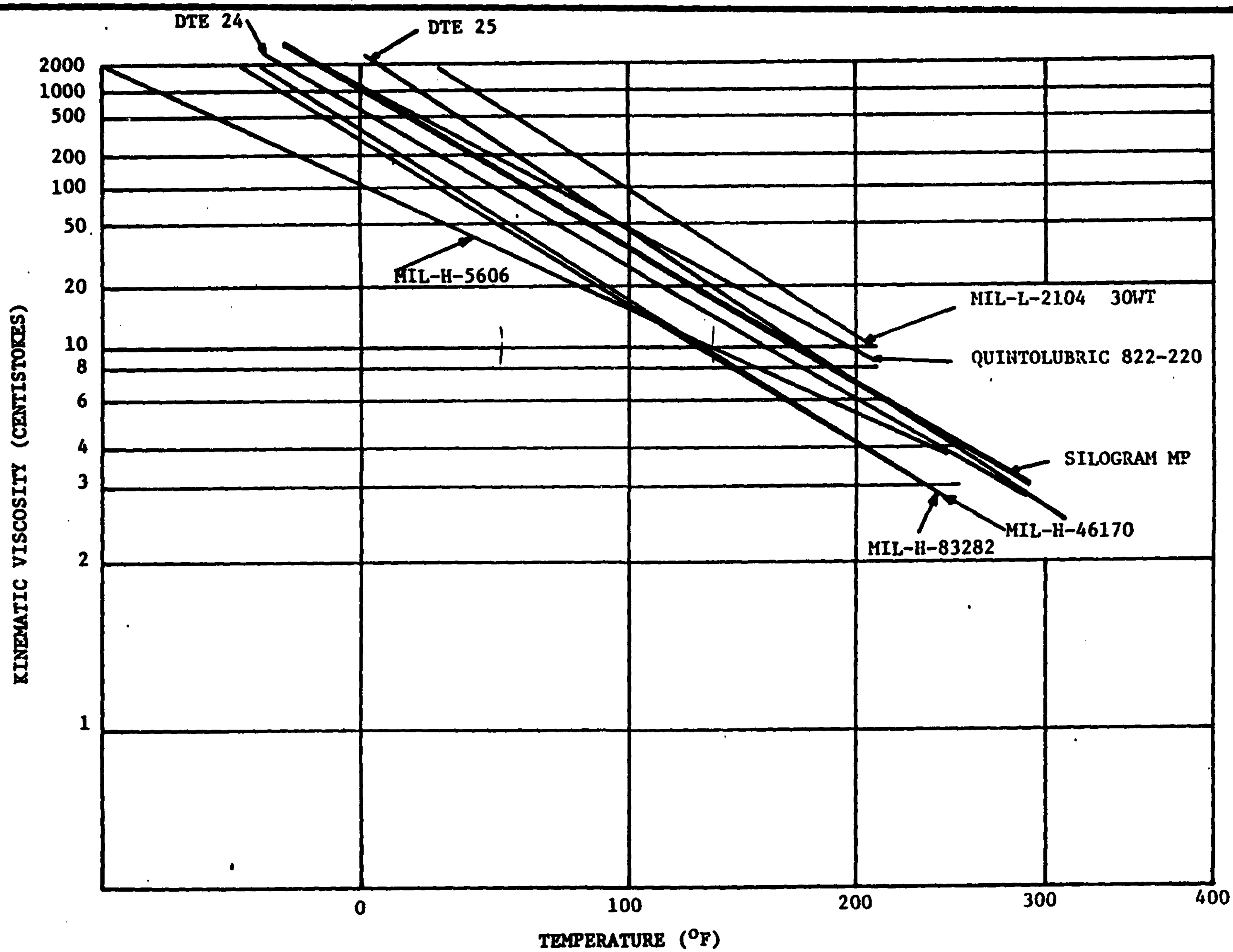


FIGURE 29, VISCOSITY VERSUS TEMPERATURE RELATIONSHIP OF HYDRAULIC FLUIDS

HYDROCARBON BASE OIL

COMPANY NAME	CATEGORY	BRAND NAME	GRADE/ CALLOUT	COLOR D-1500	POUR POINT °F	FLASH POINT °F	VISCOSITY 100°F	SUS 210°F	ISO - VG GRADE/IDENT.	VISC. INDEX	ADDITIVES (ANTI CORROSION, ANTI FOAM, ANTI OXIDANT, ANTI RUST, ANTI WEAR, DEMULSIFIER, DETERGENT, V.I. IMPROVERS)	SPEC. GRAV.
KENDALL (CTD)	TURBINE OIL	KENOIL R&O	047-EP	2	-15	400	200	47.2	46	110	X X X X X X	.8681
			053-EP	2.5	-5	415	300	53.1	68	102	X X X X X X	.8762
			065-EP	2.5	0	460	500	63.6	100	95	X X X X X X	.8789
			080-EP	3.5	10	490	785	81.2	150/220	104	X X X X X X	.8767
	LUBRICANT	HYKEN	052		-40	400	230	55.5	46	158	X X X X X X X	.8798
	PNEUMATIC TOOL & WAY LUBRICANT	KENOIL	945-EP	4.5	-20	390	175.9	46.3	32/46	120	X X X X X	.8726
			965-EP	4.5	0	420	483.9	65.5	100	110	X X X X X	.8844
			985-EP	6	15	420	888.2	87.3	150	110	X X X X X	.8952
	INDUSTRIAL OIL	KENOIL	040	3	-10	360	95.8	39.1	22	101	X X X	.8681
			045	4.5	-25	360	169.2	45	32/46	108	X X X	.8697
			051	4.5	0	410	275.1	51.3	46/68	101	X X X	.8757
			061	4.5	0	420	421.1	60.7	100	105	X X X	.8794
	GEAR TRANS-MISSION OIL	KENTRAN	080	3.5	-10	490	785	81.2	150/220	104	X X X X X X	.8767
		KENDALL COMPOUNDED GEAR LUBE	155	-	20	520	2636.4	170	460/680	100	X X X	.8927
			206	-	30	565	4501.7	220	1000	97	X X X	.8984
		3 STAR GEAR LUBRICANT	80W-140	-	-20	310	1242	128.4	220/320	140	X X X X X X	.8939
		NS-MP HYPOID GEAR LUBE	75W	-	-40	370	123.5	42.1	22/32	110	X X X X X	.8745
			80W-90	-	-30	420	916	82	150/220	100	X X X X X	.8927
			85W-140	-	0	425	2459.2	151.8	460	97	X X X X X	.9042
		ALL OIL GEAR LUBE	85W-90	-	0	360	692	77.8	150	109	X X X	.8816
			140	-	15	550	2481	158.6	460	102	X X X	.8927
			250	-	20	560	9605	399.5	-	105	X X X	.9042
		BAR & CHAIN OIL	P301W	4.5	-20	390	175.9	46.3	32/46	120	X X X X X	.8726
			P301	4.5	0	420	483.9	65.5	100	110	X X X X X	.8844
LUBRICATION ENGINEERS, INC.	ANTI-WEAR HYDRAULIC OIL	MONOLEC	6105A	RED	-25	380	112	41	22	95	X X X X X	.8602
			6110A	RED	-20	420	210	47	46	95	X X X X X	.8706
			6120A	RED	-20	440	305	53	68	95	X X X X X	.8762
			6130A	RED	-10	475	510	63	100	95	X X X X X	.8789
A. MARGOLIS & SONS	PREMIUM ANTI-WEAR HYDRAULIC OIL	SILOGRAM M.P.	157	2	-20	420	150	44	32	105	X X X X X X	.8665
			207	2.5	-20	430	205	47	46	105	X X X X X X	.8708
			307	2.5	-20	450	325	54.6	68	105	X X X X X X	.8751
			507	4.5	-20	460	462	64	100	105	X X X X X X	.8816
			707	5	-20	475	640	74	150	105	X X X X X X	.8871
			907	5.5	-20	500	926	88	220	105	X X X X X X	.8871
	PREMIUM ANTI-WEAR HYD OIL W/SEAL CON-DITIONER	SILOGRAM TIP-100	-15-7	2	-20	420	150	44	32	109	X X X X X X	.8665
			-20-7	2.5	-20	430	205	47	46	109	X X X X X X	.8708
			-30-7	2.5	-20	450	325	54.6	68	109	X X X X X X	.8751
MOBIL OIL CORP.	PREMIUM HYDRAULIC OIL	MOBIL DTE 10 SERIES	11	L1.5	-50	329	90	40	22	155	X X X X X X X X	.864
			13	L1.0	-50	329	150	46	32	150	X X X X X X X X	.876
			15	L1.5	-50	329	205	52	46	150	X X X X X X X X	.878
			16	L1.5	-50	329	300	60	68	120	X X X X X X X X	.881
			18	2.0	-40	329	465	69	100	120	X X X X X X X X	.884
			19	L5.0	-40	329	765	89	150	120	X X X X X X X X	.891
	SUPER STABILIZED ANTI-WEAR HYDRAULIC OIL	MOBIL DTE 20 SERIES	24	3.0	0	396	150/165	43.6	32	95	X X X X X X X	.867
			25	3.0	0	396	215/240	47	46	98	X X X X X X X	.873
			26	3.6	0	400	315/355	54.2	68	98	X X X X X X X	.877

4.10 Accessibility and Serviceability

Rationale for component placements in the vehicle followed the logical sequence of working from the sprockets and hull mounting faces back into available space in the vehicle.

Initially the final drive gear units were designed to locate motors as conveniently as possible. Attachment 10 drawings show this installation. Motors are located directly in the front vehicle opening and are easily accessed for adjustment or service.

With this motor arrangement, it is not possible to locate the main system pump on a conventional flywheel mounted pump drive. Rather than move the engine to a new location in the vehicle, a simple gear drive was developed which permits locating the main pump beside the engine in space previously occupied by the speed change transmission. This location for the main pump is convenient as it is accessible through a removable panel in the operator's compartment and is located near the motors in a location between the hydraulic reservoir and the motors. Attachment 10 drawings show this pump placement in the vehicle.

With drive motors and main pump placed as described above, the vehicle front compartment is uncluttered and provides ample space for auxiliary hydraulic pumps which are also shown on Attachment 11 drawings. The hydrostatic fan pump is located directly under the fan motor. The auxiliary pump is located central to the vehicle as it services both

final drive gear units as well as other functions. Both pumps are readily accessible for service or adjustment.

The main system reservoir will be located in the crew compartment as it was in previous programs.

Manifold blocks will be deck mounted as near the units they service as is practical. With main components located in this manner, ample space is provided for plumbing and control lines.

4.11 Corrosion

The vehicle was delivered in very poor condition. The undercarriage mechanisms were covered with mud and debris and the vehicle interior was filthy. The entire vehicle has since been steam cleaned and is ready for systems installation. It is stored in a heated building and it is felt that this will adequately protect it until it leaves the building for field trials.

Hydraulic components are protected through the use of plastic port plugs and commercial packaging. There is no requirement for any special considerations to prevent corrosion, prior to vehicle installation.

Exposed housings of the final drive units are specified as aluminum which will be zinc chromate primer painted prior to installation in the vehicle.

After all systems are installed in the vehicle, exposed portions of the final drive units will be painted to match the vehicle.

There was no evidence of corrosion on any of the hydrostatic components or gear drives in the system delivered with the vehicle. It is therefore assume that our components will fare equally well. Electronic components will be embedded in a silicone or foam type compound to protect them from shock and vibration. This encapsulation will also protect them from a salt air environment. Rheostats, switches etc. will be treated with a commercial spray which is used to clean and protect such devices. (Mil Spec Spray)
All ferrous material levers, linkages, controls, etc. will be primer and finish coat painted prior to installation in the vehicle.

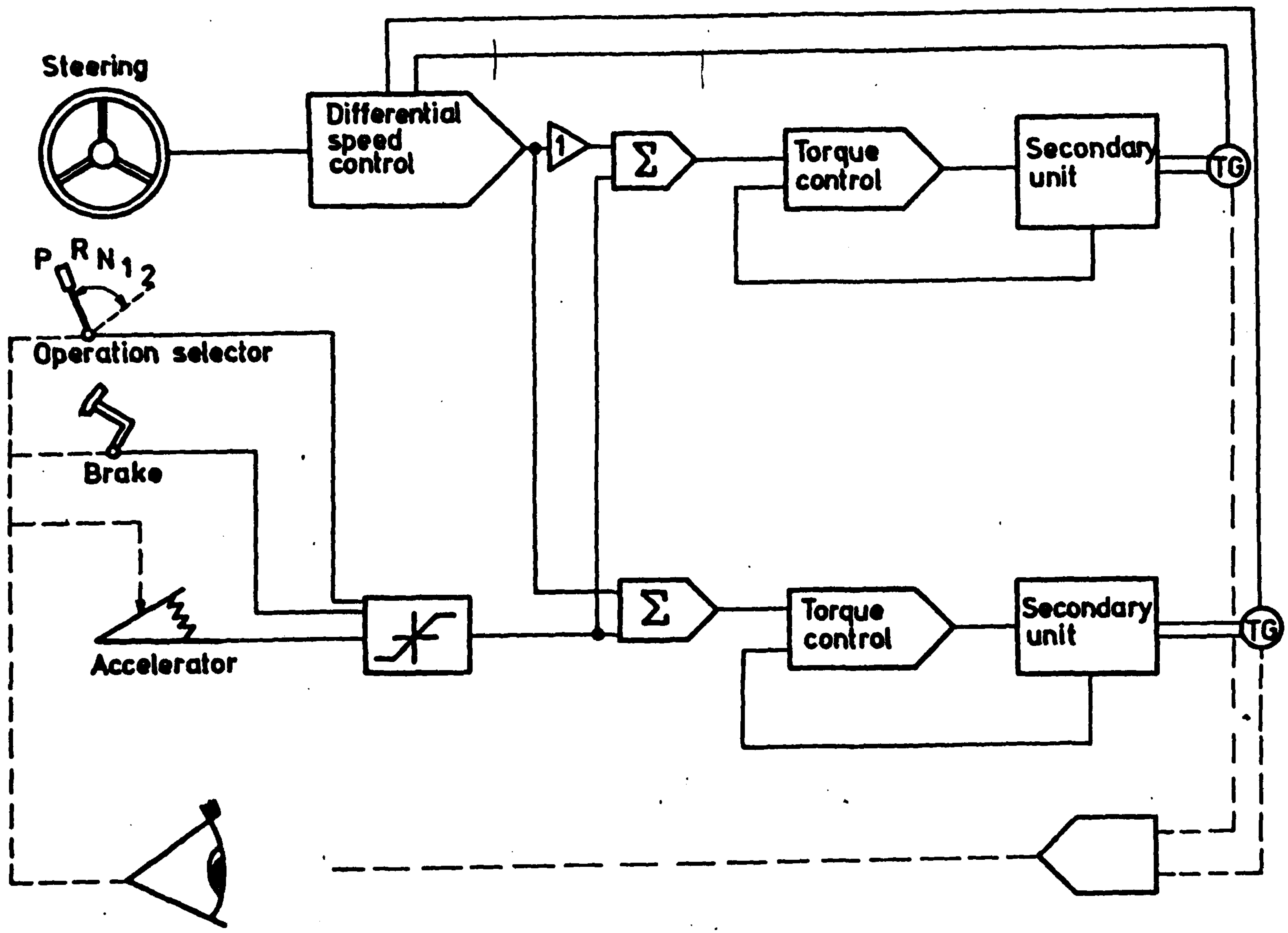
5.0 M113 HDSR System (Vehicle) Control

5.1 General

Vehicle control is to be automotive in nature with accelerator, steering, speed change and braking functions. The block diagram on the following page shows this concept.

The control system is analogue electronic which is input with potentiometer and switch control signals. Outputs to the motors and main system pump are hydraulic displacement controls through electronic proportional control valves.

At engine start-up, the speed selector is in the park or neutral position and pumps and motors are off-stroke. There is no flow or pressure in the main system.



Steering
Differential speed control
1
Σ
Torque control
Secondary unit
TG
P R N 1 2
Operation selector
Brake
Accelerator
Σ
Torque control
Secondary unit
TG

FIGURE 1

When the speed/direction selector is placed in 1, 2, or R, the pump DA control initiates system flow which establishes system pressure and the vehicle is ready for operation.

Vehicle acceleration and speed is controlled by the accelerator pedal. As the accelerator pedal is depressed, motors go on-stroke in proportion with the position of the accelerator pedal. The main pump also goes on-stroke to provide necessary flow to meet motor speed/displacement demands. The system is flow controlled in this mode. what point?

When motors and pump reach maximum displacement and the signal input is for increased speed, motors will begin to destroke to provide added speed. In this mode, the system is H.P. limited with maximum vehicle speed being limited by the maximum allowable motor speed or by H.P. in the case of climbing a grade. Braking is accomplished through hydrostatic and mechanical means.

5.2 Braking Functions

Operational braking is hydrostatic with emergency and parking brake action being provided by a multiple disc, spring applied, hydraulically released brake.

When the operator removes his foot from the accelerator, motors and main system pump go off-stroke. As the brake pedal is depressed, the motors go on-stroke acting as pumps. In order to maintain

constant system pressure, the pump is stroked in the over-center mode and braking energies are directed back into the engine. Braking action is proportional to force on the brake pedal as in an automobile. When the vehicle slows to a stop the mechanical brakes are engaged to hold the vehicle. Releasing the brake pedal restores all systems to neutral.

5.3 Vehicle Steering

Vehicle steering is accomplished by electronically biasing speed signals to the motors. Input signals are from the steering (wheel) control. There are two electronic loops for steering control.

A closed loop with speed feedback for high speed fine control and powered turns.

An open with loop direct signal control of motors for sharp turns and counter rotation.

The transition between the two loops is automatic. The mode of operation is determined by the position of the steering (wheel) control.

A vehicle speed related steering control logic is being considered. The curve on the following page shows vehicle speed vs. turn radius to keep vehicle side forces under 0.8g.

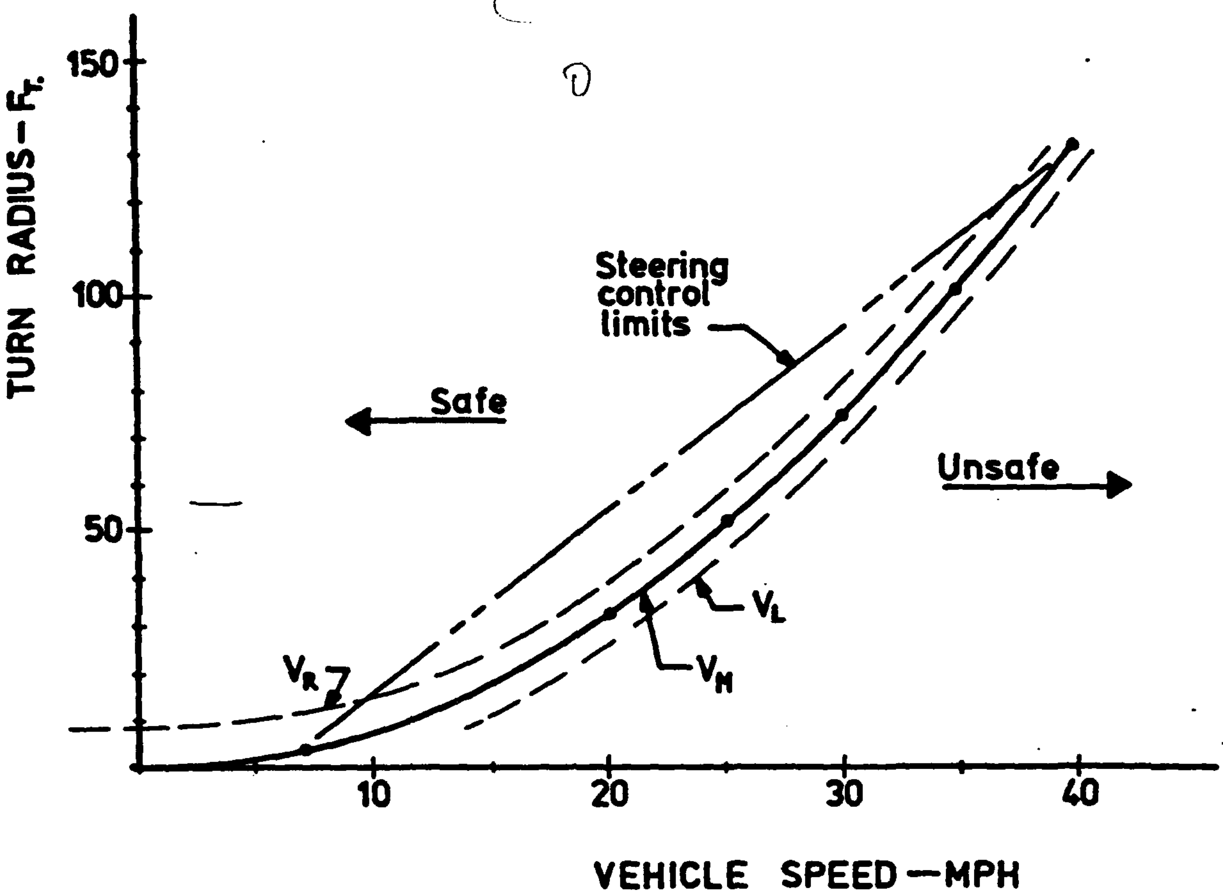

TURN RADIUS—FT.
150
100
50
10
20
30
40
VEHICLE SPEED—MPH
Steering
control
limits
Safe
Unsafe
V_R
V_L
V_M

FIGURE 2

5.4 Gear Changing

Direction control (Forward-Reverse) and speed changes (Hi-Lo) are controlled manually with a speed change lever. When a speed change from Lo to Hi gear is signaled, low gear clutches are released in the final drive units main and system pressure reduced to zero psi. The Hi gear clutches are then engaged and the pressure restored. It is estimated that a speed change will require no more than 1/2 second. It is felt that speed changes will be smooth as the clutches are required to adjust the speed (inertia) of the motor rotating groups plus fluid mass and not the mass of the vehicle. The vehicle transmission is in neutral during the speed change. WHAT?

Much of this system is made up of standard Rexroth controls. Whereas the circuit is especially designed for this application, no special components are required.

A detailed control system description is given in Attachment 13. This system is made up of standard Rexroth controls. The circuit is especially designed for this application, no special components are required.

6.0 M113 Final Drive Gearing

6.1 General

Operating requirements of the M113 specify that it must be capable of negotiating a 60% grade, accelerate from 0-20 mph in

6 seconds and must travel 40 mph. Speed and torque limits of the hydraulic motors dictate that two different final drive ratios be used to meet these requirements. Optimum final drive gear ratios to meet these requirements with Rexroth model AA4V125 motors are 8.0:1 reduction in low gear and 4.28:1 reduction in high gear. These ratios not only guarantee specified torques and speeds but provide a broad range of speed over which gears may be shifted. Attachment 5 performance curve graphically shows this capability. Attachment 6 shows the final drive gearing concept. Two hydraulic motors are mounted to the input housing and are spline coupled to gears which are in mesh with a common clutch shaft gear.

6.2 Clutch Pack Description

When a clutch pack is engaged, rotary power is then transmitted through a clutch output gear to the intermediate shaft gear. The intermediate shaft drives the sun gear of the final reduction gear set which turns the output shaft.

The clutch is a standard Rockford 7.75 - 5X5 double pack clutch. The overall gear reduction (Hi or Lo ratio) depends upon which clutch pack is engaged. When neither clutch pack is engaged, the final drive is in neutral. Clutches are engaged hydraulically and require a pressure of 200 psig to develop design torque. Attachment 6 also shows clutch data.

6.3 Bearing Description

All rotary bearings in the final drive gear reducers are low friction ball or tapered roller bearings. Minimum B-10 life is 9,000 hours at maximum torque and speed.

6.4 Gear Design Criteria

All gears in the final drives are spur gears. Spur gearing is selected to provide higher efficiency within standard gear manufacturing tolerances. All gears are to be carburized or induction hardened. Attachment 6 stress calculations show gear designs to be conservative and a long service life is expected.

6.5 Seal Considerations

Output shaft seals will be metal-to-metal face seals. This type of seal was developed by the Caterpillar Tractor Company in the 1960's to provide a highly reliable rotary seal in less than ideal operating conditions such as in water, mud, etc. These seals are the best state-of-the-art seals available for this type of service in that they keep lubricant in and contamination out. All other seals are static. RTV (Room Temperature Vulcanizing Silicone) has proven to be more reliable than gaskets and O-rings for this type of seal joint and is proposed for use here.

Although final drive gearing efficiency is expected to be high (95%), the physical location of the units in the vehicle dictate that they be cooled.

6.6 Cooling Considerations

When a clutch is engaged it is standard practice to provide a flow of cooling fluid through the clutch pack. This flow will be drained from the final drive housing and circulated through a heat exchanger and then returned through the clutch and final drive to cool the unit.

6.7 Emergency Braking

In addition to providing the means for transmission of power from the hydrostatic motors to the vehicle sprockets, an emergency stopping and parking brake is mounted to the final drive unit.
This brake is a multiple disc, oil cooled unit which is spring applied and released with hydraulic pressure. The AUSCO failsafe brakes which were supplied with vehicle will be used.

6.8 Speed Feedback

Another auxiliary function of the final drive unit is to provide a gear drive for a tach-generator which will be used as a speed measuring and monitoring device for control of the HDSR system.
A cross-section drawing of the final drive gear reducer unit is also shown in attachment 6.

6.9 Corrosion Considerations

Corrosion protection of exposed (external to the hull) portions of the final drive gear reducers will be ensured by using aluminum castings for all exposed housings. Final drive units will be solvent cleaned

and zinc chromate primer coated. After installation, the final drive units (external to the hull) will be painted to match the vehicle. In light of the fact that this vehicle and is a test bed for HDSR, it is felt that these protective measures will see us safely through a "brakish stream" enroute to the test site.

6.10 Structural Considerations

It has been requested that stress calculations be provided to verify the integrity of mountings and final drive systems under a 30,000 lb load applied radially at the sprocket. Calculations to verify unit integrity are also included in Attachment 6.

6.11 Final Drive Efficiencies

Efficiencies of the final drive are projected to range from 97% to 89% depending on speed.

6.12 Final Drive Ratings

Output speed: 700 rpm continuous, 1000 rpm (max.).

Output torque: 10,000 lb-ft, intermittent.

Side load capacity: 60,000 lb @ sprocket center line.

Rotation: Omnidirectional.

Maximum continuous input power: 150 hp with cooling flow.

Efficiencies: Low Gear: 91.5%* minimum @ 3000 rpm input.

High Gear: 89.0%* minimum @ 3000 rpm input.

Braking: Integral (bolt-on) to the final drive unit; capable of stopping a 14 ton vehicle from 5 mph on a 60% grade and hold the vehicle.

*Projected - may vary ±2% except high gear @ + 2% - 0%

6.13 Final Drive Test Procedure

Final drive units will be mounted on a frame structure designed to carry full operating torque with output shafts coupled directly to each other. Inputs of one unit will be driven by specified motors and "inputs" of the other unit will be loaded by specified motors acting as pumps which are loaded over relief valves. For test purposes, units will be loaded to rated capacity of 10,000 lb-ft output torque. Efficiencies will be calculated and compared with projected valves. The test duration will be sufficient to establish efficiency valves and structural integrity of the final drive units. In no case will this test time exceed 2 hours. No endurance testing is planned. Operating speed during testing is limited to 200 hp maximum hydraulic hp.

7.0 M113 Pump Drive

7.1 General

The prime mover in the M113 is a DDA 6V-53 diesel engine. In normal

hydrostatic drive systems, pumps are connected to the prime mover (engine) through a commercially available gear drive.

In the M113, space limitations do not permit the use of commercially available gear drives unless the engine is moved to a different location in the vehicle. Therefore, it is proposed to design and build a special gear drive unit which will be used to drive both main and auxiliary pumps. This unit is shown in Attachment 7.

7.2 Main and Auxiliary Pump Drives

The main system pump will be driven through a 1.2:1 gear reduction which keeps our pump speed below 2500 rpm which is the maximum allowed.

All auxiliary pumps will operate at up to 3000 rpm (engine speed).

Three auxiliary pumps are required. They are:

FUNCTION	REXROTH MODEL	TYPE
Hydrostatic Fan Drive	AA4V40	Axial Piston Pump
Main System Control Flow	1PF2G2	Gear Pump
Secondary Hydraulics	1PF2G2	Gear Pump

Attachment 10 also shows the physical arrangement for locating pumps in the vehicle. It should be noted that the main system pump will occupy space beside the engine which facilitates plumbing, adjusting and serviceability.

7.3 Operating Ratings

Input/output speed: 3000 rpm

Input power: 300 hp continuous

Output power:	SAE E pad:	300 hp continuous
	SAE C pad:	50 hp continuous
	SAE B pad:	10 hp continuous

Efficiency: 95% @ rated speed and hp (projected)

8.0 Auxiliary Hydraulics

8.1 General

Auxiliary hydraulic requirements are:

- Fan drive for engine radiator cooling
- Final drive
- Gear shifting
- Brake release
- Ramp actuation

8.2 Fan Drive System

The Hydrostatic Fan Drive is a closed loop high pressure hydraulic system. The pump is a Rexroth model AA4V40 variable volume axial piston design and includes its own internal make-up/charge system. This pump is directly coupled to the vehicles power plant via a gear pump drive.

Directly coupled to the vehicle cooling fan is a Rexroth AA2FM16 high pressure fixed displacement bent axis piston motor.

The fluid used in this system is the same type the vehicle HDSR system uses and consequently these two systems utilize the same return fluid treatment and storage facility, thus reducing weight and space requirements. (See Attachment 8)

The Hydrostatic Fan Drive is designed with efficiency, and an operational failsafe mode in mind.

Sensing the vehicles coolant via two thermal switches, the fan will operate at one of 3 different adjustable speeds depending on the coolant temperature.

At low temperature (below 180 degrees F) the fan will operate at a minimum speed and draws minimum H.P. As the engine temperature increases to 215 degrees F the fan will assume an intermediate speed sufficient to maintain this temperature under normal vehicle operation. At a higher than normal coolant temperature (225 F) the fan will be driven at a higher speed to provide required cooling. The fan is capable of operating at speeds up to 5000 rpm. This hydrostatic drive will enable this to be achieved if required. The hydraulic circuit for this system is shown on Attachment 8.

8.2.1 Fail Safe Features

Any loss of temperature signal will cause the fan drive system to go to full speed, thus constantly providing maximum cooling.

The HDSR hydraulic system fluid is also cooled by this fan and will provide a signal to the fan drive overriding other temperature signals so that in the event the hydraulic fluid temperature becomes excessive, the fan drive goes to maximum speed and lowers HDSR fluid temperature to its correct operating temperature of 150 degrees F.

To avoid fan overspeeding, should the diesel overspeed, a pressure override valve will sense this and destroke the pump slowing the fan as required.

The hydrostatic system is protected from over pressure with a high pressure relief valve internal to the pump.

Fan run-on after diesel shutdown is handled by cross port reliefs internal to the pump.

Fan interruptions caused by foreign matter entering the fan are absorbed by either the pump's high pressure relief or its cross port reliefs.

This Hydrostatic Fan Drive System is ideally suited for this application in that it truly reacts to the vehicle cooling requirements and is not dependent on engine speed.

This system has recently been subjected to military testing aboard an M110 as part of that vehicle's improvement program. The test results support all system design intents in that it performed all tests satisfactorily without any failures. System efficiency surpassed expectations.

The Hydrostatic Fan Drive System is completely adjustable and may be fine tuned after installation. These settings are then fixed and are repeatable on a production basis.

8.3 Transmission Cooling

Hydrostatic transmission cooling fluid flow is provided for in the main system circuit (Ref. Attachment 1). We plan to use the fluid-to-air heat exchanger furnished with the vehicle for hydrostatic transmission cooling.

8.4 Gear Changing Ramp Operation and Braking

All other auxiliary system requirements will be accomplished with the low pressure, open loop hydraulic circuit shown on Attachment 8. The main pump for these services will be a Rexroth model 1PF2G2 tandem gear pump which will operate at two pressure settings. For normal vehicle operation system pressure will be 250 psig which will shift clutch packs (gears), release the parking brake and provide cooling flow for the final drive gear units. The second presssure setting is 1500 psig and is used to raise the vehicle ramp. In this operating mode, low pressure circuits are blocked and the parking brake set. Cooling flow will be passed through a shell and tube heat exchanger with heat being transferred to engine coolant.

For hydraulic circuit details see Attachment 9.

8.5 Hydraulic Lines and Fittings

8.5.1 General

A. All flexible lines will have permanent crimp type fittings at each end.

B. All flexible hose fittings subjected to less than 3000 psi will be SAE 37 degrees (J.I.C.) swivel type.

C. All line fittings subjected to between 3000 and 6000 psi working pressure will be SAE flange type.

D. Flexible lines subject to 6000 psi working pressure will be Stratoflex No. 5240.

E. All flexible lines are "Hi-Impulse" rated.

F. All threaded ports are SAE J514j unless otherwise noted.

8.5.2 Central Hydraulic System

6000 psi and drawing number

8.5.2.1 Item 1.0, Main Pump

A. Suction Port S 1 5/8 - 12 UNF-2B (MWP, ATM)

-Connection to reservoir is 1 1/2" flexible hose SAE 100 R4 (reservoir connection will "T" off to feed fan drive pump)

B. Work Port A, 1", 6000 psi, 4 bolt flange (MWP-6000 psi)

-Flexible connection to 2" SCH XXS motor supply header will be 1 1/2" Stratoflex 5240 hose.

C. Case Drain Ports T, 1 5/8 - 12 UNF-2B (MWP, 50 psi)

-Connection to return header via 1 1/4" flexible hose SAE 100 42A Hi-Impulse.

D.. Control Port X2 7/16 - 20 UNF-2B (MWP 400 psi)

-Flexible connection to hard line 3/8 x 0.035 steel tube is hose SAE 100 R2A Hi-Impulse.

E. Work Return Port B 1" 4 bolt flange, 6000 psi (MWP 500 psi)

-Flexible connection to return header will be SAE 100 R2A hose.

8.5.2.2 Item 2.0, Drive Motors

A. Work Ports A, 1" 6000 psi 4 bolt flange (MWP 6000 psi)

-Flexible connection to 2" supply header will be 1" Stratoflex 5240 hose.

B. Case Ports, T 1 5/16 - 12 UNF-2B (MWP 50 psi)

-See Main Pump (C)

C. Work Return Port B

-See Main Pump (E)

8.5.2.3 Item 5.0, High Pressure Accumulator (MWP 6000 psi)

1 1/4" hard connection

8.5.2.4 Item 6.0 Low Pressure Accumulator (MWP 500 psi)

1 1/4" hard connection

8.5.2.5 Items 3.0, 4.0 and The Pressure Reducing Valve (MWP 6000 psi)

-Connection to central system hi-pressure via line 20.7 is 1/4" tube w/Ferlock type fittings.

8.5.3 Item 1.0 Hydrostatic Pump

A. Suction Port S 7/8-14 UNF-28 (MWP, ATM)

-Flexible connection to main hydraulics circuit pump inlet line, SAE 100R4

B. Work Port A 3/4" 6000 psi 4 bolt flange (MUP 5000 psi)

-Flexible connection to hard line supplying motor Port A is 3/4" 6 spiral wire hose, Aeroquip No. FC273

-Hard Line is ASTM A53 Grade B seamless pipe 3/4" SCH 160

C. Work Return Port B 3/4" 6000 psi SAE 4 bolt flange (MWP 500 psi)

-Flexible connection to hard line supplying motor port B is 3/4" SAE 100 R2A

-Hard Line is ASTM A53 Grade B seamless pipe 3/4" SCH 40

D. Case Drain, Port T 7/16-20 UNF-2B (MWP 50 psi)

-Flexible connection to return collector 1/2" SAE 100 R2A hose.

E. Control port CP 3/8-18 J.I.C. 37 degree male flare (MWP 400 psi)

-Flexible connection to locally located control valve assembly Port P is 3/8 SAE 100 R2A hose.

8.5.3.1 Item 2.0 Hydrostatic Motor

A. Work Ports A + B 1 1/16-12 UNF-2B (MWP 5000 psi)

-Hard Plumb, see Hydrostatic Pump notes B & C

B. Case Drain T 9/16-18 UNF-2B (MWP 50 psi)

-Hard Plumb, 1/2" tube

8.5.3.2 Item 3.0 Control Valve Manifold

A. Control Port P, See Hydrostatic Motor Note E

B. Tank Port 9/16-18 UNF-2B (MWP 50 psi)

-Hard Line connection to Reservoir Return Collector 3/8" tube

8.5.3.3 Item 4.0 Filter Assembly (MWP 400 psi)

A. Supply and Return Ports, 3/4-16 UNF-2B

-Flexible connections to Hydrostatic Pump via SAE 100 R2A hose.

9.0 M113 VEHICLE TEST PLAN

9.1 General

Vehicle testing by Rexroth will be done in two steps. Step I will be static and will ensure system conformance to plan.

Step II will evaluate the installed systems under normal vehicle operating conditions.

These tests are to ensure that vehicle systems are operating as designed to operate, the vehicle is safe and meets specified performance parameters. Testing will be conducted in two phases; static testing and dynamic testing.

9.2 Static Testing

Static testing will be conducted with the M113 vehicle blocked up and track mechanisms removed.

Static testing will follow these steps for hydraulic systems start up.

9.2.1 Check plumbing for correct hook-up and joint tightness.

9.2.2 Check fluid levels.

9.2.3 Bleed air from hydraulic systems.

9.2.4 Check engine systems per technical manual.

9.2.5 Check to ensure that all hydraulic controls are in start-up position.

9.2.6 Start engine.

9.2.7 Check for leaks.

9.2.8 Adjust fan drive system.

9.2.9 Check throttle control for proper operation.

9.2.10 Operate ramp circuit.

9.2.11 Release parking brakes.

9.2.12 Ensure neutral position of final drives.

9.2.13 Check foot brake for proper operation.

9.2.14 Check clutch pack engagement using manual shift.

9.2.15 Return final drives to neutral.

9.2.16 Start main hydrostatic drive system.

9.2.17 Check right sprocket low gear forward & reverse operation.

9.2.18 Check right sprocket high gear forward operation.

9.2.19 Check left sprocket operation.

9.2.20 Check simultaneous sprocket operation.

9.2.21 Install track mechanisms and complete all drive system adjustments.

Throughout all static testing, system pressures and temperatures will be monitored and recorded. During sprocket rotation checks, sprocket rpm vs engine rpm will be monitored and recorded in order to ensure that projected vehicle speeds are being achieved.

Vehicle projected turning characteristics will be checked by measuring differential sprocket rpm's at various steering control positions and comparing these to the algorithms of the steering control system.

Static testing will end when all systems have been checked and are known to be operating as designed and it is felt that the vehicle is safe to drive.

9.3 Dynamic Testing

9.3.1 General

Dynamic testing will begin at Rexroth Bethlehem to the extent that the basic vehicle on-board and mobile functions will be road tested and confirmed.

After adjusting the systems, dynamic testing will continue at a location suitable to perform field trials for this type vehicle.

Dynamic testing will measure the following parameters:

- Vehicle speed (low and high gears)
- Vehicle acceleration from 0-20 mph, 6 seconds
- Gradeability @ 60% slope
- Steering evaluations
- Road test to ensure that cooling systems are working adequatly and that there are no hydraulic leaks

9.4 Data Acquisition Plan

9.4.1 General

There will be installed on the vehicle at this time an "on-board" data acquisition and storage system. This system will undergo static tests paralleling the vehicle static testing and the two sets of results compared to confirm proper operation of the on-board data acquisition system.

This data acquisition system will measure pump and motor displacements, pump and motor speeds, pump and motor pressures, and system temperatures.

9.4.2 Data Reading Equipment

The data acquisition system that is planned to be used is manufactured by the "Optim Electronics Corp.", of Gainsville, MD. Their model "Megadac 2000" is intended. This is a 128 channel recorder capable of 20,000 samplings per second. It operates on a 12 or 24 volt DC supply voltage, is mobile, terrain tested, and has single magnetic tape sample character storage to 6 megabytes. This system is versatile and will accept a broad range of inputs. The input signal devices are not provided by "Optim". The following list identifies the types of sensors to be used and

their manufacturers:

Measurement	Type	MFG
Pressures	Strain gage	Omega Inc.
Speeds	Pulse train	Redlion Inc.
Temperatures	RTD	Omega Inc.
Pump/motor displacements	Inductive position indicator	Rexroth

The attached "Channel Identification List" identifies each recorder channel by number, calls out the component it is assigned to, the type of measurement being monitored and the units of measure. These exact channel descriptions will head the columns of data which also, upon command, may be printed. (See data record example)

During dynamic tests the vehicle operator will verbally describe the maneuvers of the vehicle. His descriptions will be recorded. This recording, the data stored by the data acquisition system, and known or pre-measured component performance data will be combined to provide an accurate vehicle HDSR system evaluation. Rexroth's final test report will directly address this evaluation and provide confirmation profiles of HDSR system speeds, torques, temperatures, and overall efficiencies.

9.4.3 Automatic Calculation

At Rexroth's discretion a software package may be added to the data acquisition system to aid in data evaluation. An example of this follows:

Example 1.0 (Bracket of Time; Overall Power and Efficiency)

Vehicle Operation: (measured and operator described)

Speed - 20 mph (high gear)

Soil - Hard clay

Grade - Flat

Direction - Straight

Measured:

Channels (See Channel Identification Sheet)

Evaluation:

A. Input H.P. (B.H.P.) = [[CH.12 x [CH.10 x (charge pump disp./231)]]/1714] x Eff.] + [[CH. 13 x [CH. 10 x (CH. 16 x 15.25)/231]/1714] x Eff.]

B. Tractive H.P. = [[CH.29 x [(CH. 17 - CH. 18) x[CH. 22 + CH. 23 + CH. 24 + CH. 25)/4]] x 2 x (Eff.) x 4.286 x (Eff) x 12]/63025

C. Input H.P./Tractive H.P. = Overall Efficiency

Example Notes:

- Eff. = Efficiencies as premeasured.

- Intended software package would be expanded on efficiencies to calculate effects of fluid conditions.

- Intended software will also provide data from its evaluation of performance during power turns by summating each final drive independently and comparing these to input power levels.

Acquired data will permit us to determine the following:

- Main pump spped, flow, pressure temperature and efficiency.

- Port motors speed, flow pressure temperature, and efficiency.

- Starboard motors speed, flow, pressure temperature, and efficiency.

With this acquired data we can plot the following:

- Sprocket torque as a function of vehicle speed for various operating (soil and grade) conditions.

- Sprocket torque requirements in powered turns.

- Regeneration capabilities in powered turns.

- Sprocket torque requirements in counter rotation for various operating (soil) conditions.

- HDSR component and system overall efficiencies.

M113

HDSR

DATA ACQUISITION

CHANNEL IDENTIFICATION LIST

1 Accelerator Position % Δ Norm.	2 Accelerator Signal MA.	3 Steering (WHP) Position North - 0°	4 Steering Signal +MA/-MA	5 Brake (Foot) Position % Δ Norm.
6 Brake (Foot) Signal MA	7 Brake (Hand) Position On/Off	8 Brake (Hand) Signal VDC	9 Trans. Select Position D-D1-N-R	10 Engine Speed RPM
11 Engine Fuel Consumption GPM	12 Main Pump Inlet PSI	13 Main Pump Outlet PSI	14 Main Pump Control Pr. PSI	15 Main Pump Case Pr. PSI
16 Main Pump Stroke %	17 Motors 1-4 Inlet Pr. PSI	18 Motors 1-4 Outlet Pr. PSI	19 Motors 1-4 Case Pr. PSI	20 Motors 1-2 Speed RPM
21 Motors 3-4 Speed RPM	22 Motor 1 Stroke %	23 Motor 2 Stroke %	24 Motor 3 Stroke %	25 Motor 4 Stroke %
26 Final Drive Clutch 1 PSI	27 Final Drive Clutch 2 PSI	28 Final Drive Brake PSI	29 Port Sprocket Speed RPM	30 Starboard Sp. Speed RPM
31 Vehicle Acceleration Ft/Sec^2	32 Vehicle Velocity Ft/Sec	33 Vehicle Deceleration Ft/Sec^2	34 Vehicle Coolant F^o	35 Fan Drive Press. (Hi) PSI
36 Fan Drive Press. (Lo) PSI	37 Fan Drive Fan Speed RPM	38 Ramp Circuit Pr. PSI	39 Aux. Hyd. Press. PSI	40 Aux. Hyd. Res. Temp. F^o
41 Main System Res. Temp. F^o	42 Main System Leakage Temp. F^o			

NOTE: Channels 12, 13, 14, 15, 17, 18, 19, 34, 35, 38 and 39 will be monitored by pressure guages mounted in the passenger's comparment.

SPECIFICATIONS

MEGADAC 5000 Series

Maximum sampling speed:	250,000 samples-per-second
Sampling speed range:	0 to 250,000 Hz
System gain:	1:1 to 500:1
System resolution:	12- or 14-bit
Limit functions:	AND-1, AND-2, OR
Alarms:	4 external
Alarm/Limit Comparison:	$=, \neq, <, >$
Channel scan rates:	1 primary, 3 sub-multiplexed
Channel sample order:	Any order
Channels per scan:	Any channel may occur any number of times in one scan cycle
Clock source:	Internal or external
Host interfaces:	RS-232-C, IEEE 488
Microprocessor:	80186
Parallel unit operation:	Units can be stacked to multiply throughput speed
Non-volatile RAM:	4 megabytes expandable to 8 megabytes
Maximum input channels	
5200C:	128
5210C:	80
5300C:	256
Maximum analog output channels	
5200C:	64
5210C:	40
5300C:	128
Mass storage:	60 Megabyte cartridge tape, 9-track magnetic tape
Display:	320 character LCD
Keyboards:	16-key function selector, 12-key numeric
Power:	110 V ac, 60 Hz, 120w
Options:	220 V ac, 50/60 Hz 12 V dc battery @ 8A 24 V dc battery @ 4A
Size (l x w x h)	
5200C (inches):	21 x 19 x 12.25
(centimeters):	(53 x 48 x 32)
5210C (inches):	15 x 15 x 14.5
(centimeters):	(38 x 38 x 37)
5300C (inches):	21 x 19 x 17.5
(centimeters):	(53 x 48 x 44)
Weight	
5200C:	35 to 58 lbs (15 to 26 kg)
5210C:	28 to 41 lbs (12 to 18 kg)
5300C:	42 to 65 lbs (19 to 29 kg)
Environment:	+4° to +45°C, 10 to 80% non-condensing humidity

MEGADAC 2000 Series

Maximum sampling speed:	20,000 Hz
Sampling speed range:	0 to 20,000 Hz
System gain:	1:1 to 8000:1
Alarm limit:	High, low or none
Channel sample order:	Any order
Channels per scan:	Any channel may occur any number of times in one scan cycle
Clock source:	Internal or external
Host interface:	RS-232-C, IEEE 488
Microprocessor:	80186
Parallel unit operation:	Units can be stacked to multiply throughput speed
Non-volatile RAM:	128 k bytes standard, expandable to 512 k bytes
Maximum input channels	
2200C/2210C:	128
2300C:	256
Maximum analog output channels	
2200C/2300C:	32
2210C:	20
Mass storage:	60 Megabyte cartridge tape, 9-track magnetic tape
Display:	80 character LCD
Keyboards:	16-key function selector, 12-key numeric
Power:	110 V ac, 60 Hz, 120 w
Options:	220 V ac, 50/60 Hz 12 V dc battery @ 8 A 24 V dc battery @ 4 A
Size (l x w x h)	
2200C (inches):	21 x 19 x 12.25
(centimeters):	(53 x 48 x 32)
2210C (inches):	15 x 15 x 12.5
(centimeters):	(38 x 38 x 32)
2300C (inches):	21 x 19 x 17.5
(centimeters):	(53 x 48 x 44)
Weight	
2200C:	35 to 58 lbs (15 to 26 kg)
2210C:	28 to 41 lbs (12 to 18 kg)
2300C:	42 to 65 lbs (19 to 29 kg)
Environment:	+40° to +45°C, 10 to 80% non-condensing humidity

MEGADAC 200 Series

Resolution	
ADC:	16 bit
Voltage:	1 microvolt
Strain:	0.1 microstrain
Temperature	
Thermocouple:	0.02° C
RTD:	0.001° C
ADC dynamic range:	± 32767 counts
ADC calibration:	± 30000 counts
Microprocessor:	Z80
Full scale voltage input:	± 10 volts
Excitation	
Voltage:	0 to 20.0 v in 0.1 volt steps
Current:	0 to 16.0 mA in 0.1 mA steps
Common mode rejection:	>165 dB at line frequency
Normal mode rejection:	>90 dB at line frequency
Accuracy:	± 0.02% ± 2 counts
Linearity:	± 0.003% ± 2 counts
Temperature coefficient:	± 0.002% per ° C
Input impedance:	>100 megaohms
Channel isolation:	>10,000 megaohms
Host interface:	RS-232-C
Baud rate:	Auto-select at power up (300-9.6k)
Input power:	110 V ac, 60 Hz, 100 w
Option:	220 V ac, 50/60 Hz
Size (l x w x h)	
100 (inches):	18 x 20 x 14
(centimeters):	(46 x 51 x 36)
200 (inches):	18 x 20 x 22
(centimeters):	(46 x 51 x 56)
Weight	
100:	50 to 72 lbs (22 to 32 kg)
200:	56 to 100 lbs (25 to 45 kg)
Temperature range	
Operating:	0° to +45° C
Non-operating:	−25° to +75° C
Humidity:	0 to 90%, non-condensing

OPTIM ELECTRONICS CORPORATION

US Sales (except Maryland) 1-800-345-5110

Middlebrook Technology Park
12401 Middlebrook Road
Germantown, MD 20874
Telephone (301) 428-7200
Telex 898139

DATA RECORD (PRINT OUT)

40	41	42	43	44	45	46	47	48
FWD MOTOR PRESS (PSI)	REV MOTOR PRESS (PSI)	CASE DRAIN PRESS (PSI)	DISP PRESS (PSI)	FUEL FLOW RATE (LB HR)	CALC PUMP DISPL (IN3-REV)	CALC MOTOR DISPL (IN3-REV)	CALC PUMP VOL EFF (RATIO)	CALC PUMP MECH EFF (RATIO)
1043.7	211.58	45.06	316.95	7.98	.33	11.36	.11	.11
1711.7	223.31	46.27	314.74	8.56	.21	11.36	.11	.11
975.92	765.33	28.16	303.10	9.59	1.43	11.36	0.00	0.00
1789.8	765.20	26.41	293.33	10.80	1.19	11.36	0.00	0.00
2519.0	765.08	29.51	286.19	11.82	1.12	11.36	0.00	0.00
3056.4	72.97	44.90	317.54	12.81	.92	11.36	0.00	0.00
3711.6	134.46	45.75	317.41	14.57	.75	11.36	.11	.62
4535.0	214.71	45.37	318.65	16.05	.48	11.36	.11	.51
945.88	764.98	28.23	306.73	10.40	2.73	11.36	0.00	0.00
1736.8	764.89	26.28	295.31	12.49	2.52	11.36	0.00	0.00
2411.0	764.81	29.34	267.99	14.89	2.35	11.36	0.00	0.00
3146.4	764.79	27.17	273.07	16.66	2.00	11.36	0.00	0.00
3713.6	87.91	44.48	317.41	20.13	2.13	11.36	0.00	0.00
4323.6	260.88	44.36	318.89	22.62	[illegible]	11.36	.68	.87
4291.0	280.29	44.89	318.45	23.16	1.66	11.36	.68	.86
992.80	764.78	27.13	300.73	[illegible]	4.32	11.36	0.00	0.00
[illegible]	764.76	27.36	295.28	[illegible]	4.19	11.36	0.00	0.00
[illegible]	290.35	27.53	[illegible]	[illegible]	4.49	11.36	.92	.90
[illegible]	764.71	28.47	[illegible]	21.33	3.55	11.36	0.00	0.00
4277.4	220.89	[illegible]	[illegible]	29.03	3.17	11.36	.86	.92
4360.8	146.08	[illegible]	310.65	29.12	3.24	11.36	.86	.93
4863.2	355.02	[illegible]	310.69	32.05	2.69	[illegible]	.82	.92
1994.5	782.49	27.50	292.30	18.57	6.12	[illegible]	0.00	0.00
2744.6	781.17	28.21	274.35	23.42	5.92	[illegible]	0.00	0.00
3338.8	783.49	28.22	233.56	27.22	[illegible]	11.36	0.00	0.00
3546.8	783.08	29.85	176.38	27.32	[illegible]	11.36	0.00	0.00
4838.4	176.85	43.72	312.86	[illegible]	[illegible]	11.36	.90	.95
2211.1	782.50	29.68	286.10	[illegible]	6.12	9.81	0.00	0.00
2909.4	782.63	29.71	249.90	[illegible]	6.12	11.05	0.00	0.00
3446.6	782.58	26.31	213.62	28.10	5.50	11.36	0.00	0.00
3554.0	783.16	27.17	179.36	27.60	4.17	11.36	0.00	0.00
2621.8	784.54	29.19	282.29	22.86	6.12	8.29	0.00	0.00
3130.6	785.38	29.31	243.52	25.81	6.12	10.44	0.00	0.00
3691.4	297.85	43.46	316.01	29.05	6.12	9.40	.93	.95
2739.2	13.13	26.21	268.66	23.47	6.12	8.65	0.00	0.00
3085.4	10.90	26.61	229.13	25.90	6.12	11.36	0.00	0.00
3253.4	9.60	27.31	196.96	26.35	4.94	11.36	0.00	0.00
4159.2	145.08	42.25	314.98	32.63	6.12	5.86	.93	.96
4704.1	-102.7	98.81	313.53	35.36	6.12	5.58	0.00	0.00

EXAMPLE ONLY

EXAMPLE ONLY

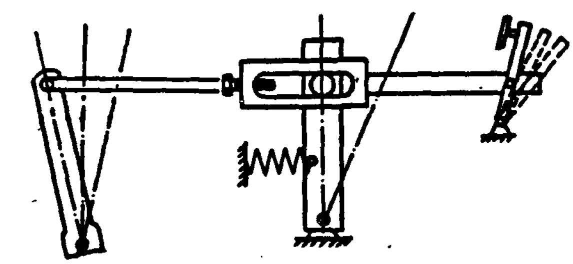
10.0 M113 HDSR Engine Speed Control

10.1 General

Engine speed level is controlled by the position of the accelerator pedal. Engine speed is maintained at the selected level by the main pump DA control.

10.2 Rexroth DA Control

As explained on page 8 of RA 06202 (Attachment 1) the DA control responds to changes in engine speed. As engine speed increases, pump displacement is increased in direct proportion with engine speed. In the HDSR system we plan to begin stroking the pump at 1000 rpm and reach maximum displacement at 2200 rpm (max. torque). Above 2200 rpm, the DA control cartridge range is adjusted upward to maintain speed control should external engine loads begin to pull engine rpm down. The accelerator pedal which was furnished with the M113 vehicle will be used to control engine speed level. Connection between the accelerator pedal, the DA cartridge range control, and the engine will be mechanical linkage as shown pictorially here.



If engine rpm begins to decrease below the level selected by the accelerator pedal, the main pump is automatically destroked to a displacement which allows the engine to maintain selected speed. The DA control is a widely used control and is proven to be effective in automotive type control of hydrostatic drives. Rexroth recommends the DA control with direct (hydro-mechanical) engine speed control because of its proven reliability.

10.3 Electronic Control

In the event that it is deemed appropriate to use an electronic speed control, Rexroth will use an electronic controller that responds to signals from the HDSR control circuits to manage engine speed. Engine management systems are off the shelf available from Dowty Electronics (Controls Division). However, sufficient engine fuel consumption data is required that has not been readily available to this point in order for an effective application analysis to be carried out. The electronic system concept is outlined in Attachment 12.

It is felt that an electronic approach to engine management may overcomplicate a program to explore the benefits of a new concept in hydrostatic power transmission. The DA pump control essentially takes engine management out of the development equation and in Rexroth's view it should be used.

11.0 Projected Vehicle Performance

11.1 General

For very basic reasons, the HDSR system will out perform closed loop hydrostatic drives previously tested..

11.2 Expected Improvements Over Conventional Drives

The reasons are as follows:

- Larger motor displacements of the HDSR system will develop more power to drive the vehicle. If more power is not available from the engine, increased motor displacement lowers pressure to accomplish the same work and improves efficiencies.
- HDSR control requirements will enhance vehicle control and power management over dual path, closed loop systems. State-of-the-art hydraulic plumbing will improve power transmission efficiency.
- The previously installed system incorporated line sizes which were too small, used inefficient fittings (90 degree drilled fittings), which created substantial parasitic losses.
- The fact that drive sprockets were 1/2 in. out of line with track rollers had to offer some friction losses in the previous system. This will be corrected.

- Automatic and direct regeneration of power from the inside track to the outside track in powered turns offers improvement in vehicle energy management. This is the largest single drawback in conventional hydrostatic power transmission to tracked vehicles. The HDSR circuit overcomes this drawback in a very basic and simple manner.

Substantiation of basic operating requirements is shown in the HDSR system description section of this report. This shows that the proposed HDSR system will propel the vehicle at speeds up to 40 mph and will develop sufficient drawbar pull to negotiate a 60% slope at 3 mph.

11.3 System Efficiencies

Hydrostatic drive efficiencies vary in relationship to the following factors:

Pressure

Speed

Displacement

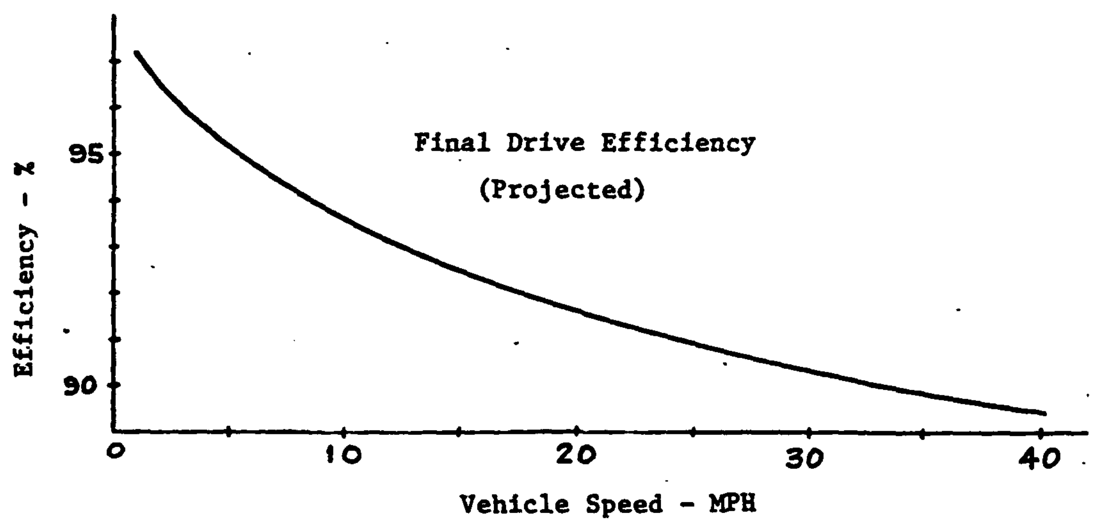
Line size, plumbing arrangement and fluid properties.

Further losses come from gear drives and auxiliary system losses. In general terms, HDSR hydraulic system efficiencies follow these rules:

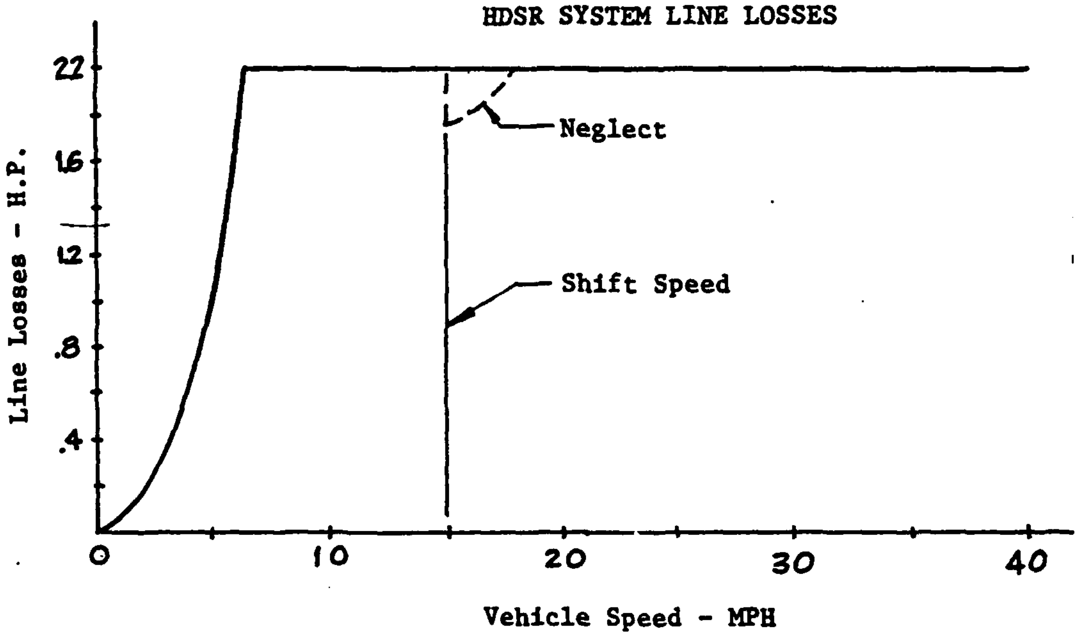
- As pressures increase, volumetric efficiencies increase and mechanical efficiencies decrease.

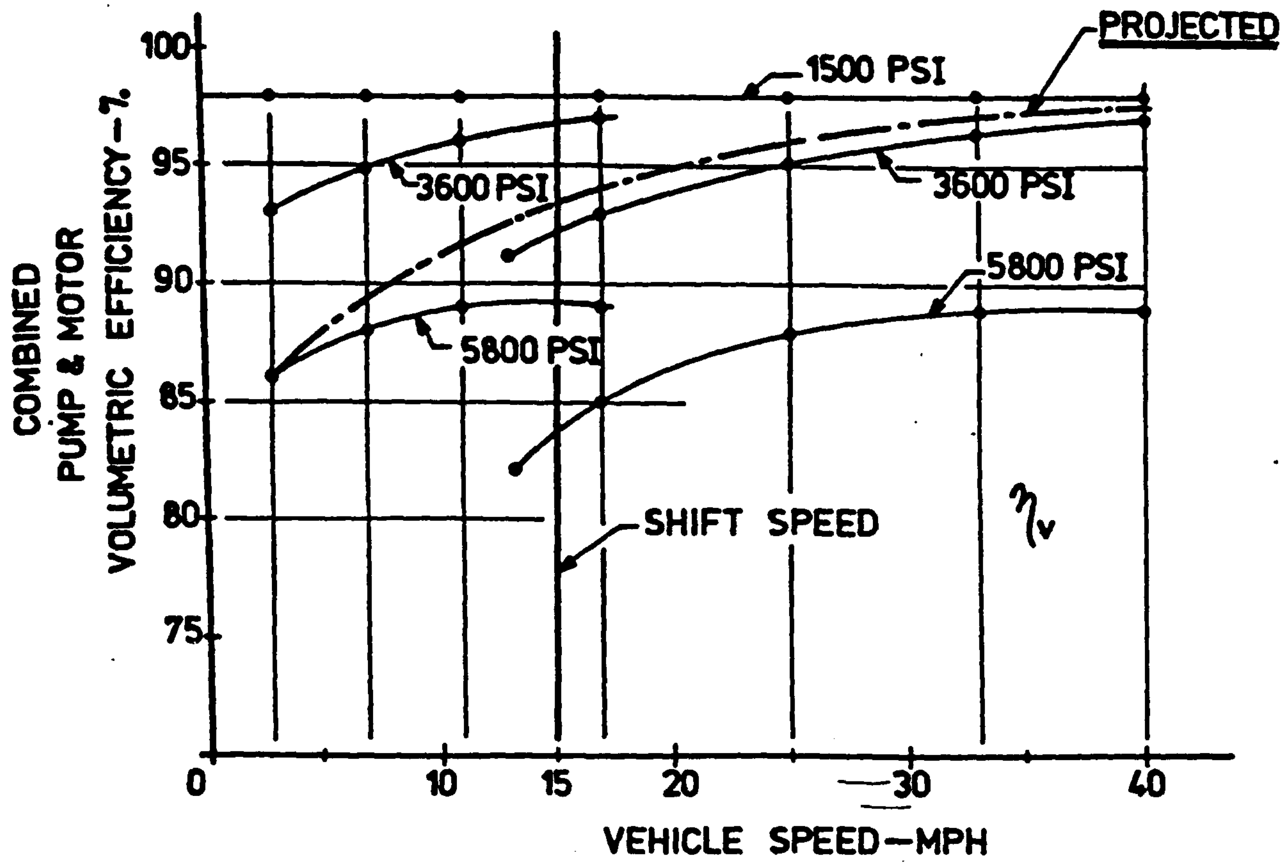
- As rotating speeds increase, volumetric efficiencies increase. Mechanical efficiencies increase from slow rotating speeds through mid-range and decrease at higher speeds.
- As displacements are increased, volumetric efficiencies improve. Mechanical efficiency variations as a function of displacement are negligible.
- Line losses are a function of line sizes, fluid properties, line lengths, fitting types, general arrangement, and flow.
- Once established, system line losses are a function of flow and temperature. In this analysis, fluid properties are assumed constant at 150 SUS and 1.0 specific gravity.

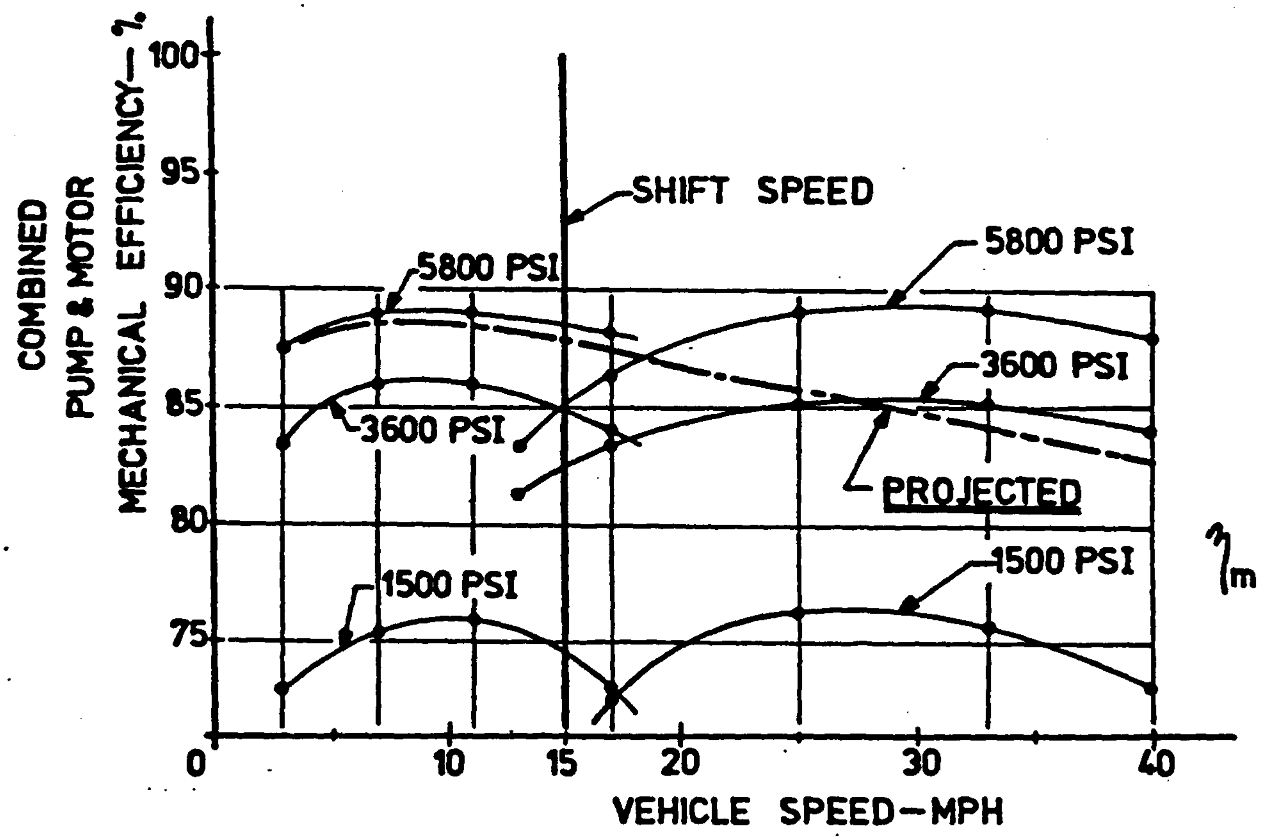
Projected HDSR system efficiencies are shown on the following graphs:



HDSR SYSTEM LINE LOSSES







Curves are base on:

- Constant pump speed @ 2500 RPM
- Pressure decreases linearly with speed from 5800 to 2750 PSI

The HDSR system being constant pressure in nature allows projected overall system efficiency as a function of vehicle speed. In the proposed system, pressure is decreased linearly from 5800 psi at 3.2 MPH to 2850 psi at 40 MPH to improve overall efficiency. This is shown as the projected efficiency on the graphs.

It is to be noted that individual component (Pump/Motor) efficiencies are based on average values for new units. We know that efficiencies of these units improves after a run-in period and therefore consider the valves to be somewhat conservative.

Efficiency Summary: (Worst Case):

Speed MPH	Other* Loss-HP	HDSR Eff.	HDSR Loss-HP	Line Loss-HP	Final Dr. Loss-HP	Total Loss-HP	O/A Eff. %
3	63	.76	57	4	7	127	58
5	63	.77	55	10	9	128	57
10	63	.80	47	22	12	124	59
15	63	.81	45	22	13	123	59
20	63	.83	40	22	16	121	60
30	63	.82	42	22	17	124	59
40	63	.81	45	22	19	129	57

* 46 HP Fan, 10 HP Pump Drive, 2 HP Aux. Hyd., 5 HP Boost Pump.

In most operating modes the fan will not be operating at 5000 RPM. Under normal ambient conditions we estimate fan losses to be 23 HP which places "other loss" at 40 HP Total. Also, 2% efficiency improvements will accrue after a 50-70 hr. run-in of HDSR components.

Efficiency Summary (Projected):

Speed MPH	Other Loss-HP	HDSR Eff.	HDSR Loss-HP	Line Loss-HP	Final Dr. Loss-HP	Total Loss-HP	O/A Eff. %
3	40	.78	57	.4	7	104	65
5	40	.79	55	1.0	9	105	65
10	40	.82	47	2	12	101	66
15	40	.83	44	2	13	99	67
20	40	.85	39	2	16	97	68
30	40	.84	42	2	17	101	60
40	40	.83	44	2	17	103	66

12.0

M113
HDSR HARDWARE INSTALLATION
WORK BREAKDOWN STRUCTURE (WBS)

WBS LEVEL 1	2	DESCRIPTION 3	WBS NUMBER
HDSR Transmission			1.0
	HDSR System Hardware		1.1
		Integration and Assembly	1.1.1
		Main System Pump	1.1.2
		Auxiliary System Pumps	1.1.3
		Pump Drive	1.1.4
		Main Drive Motors	1.1.5
		Auxiliary System Motors	1.1.6
		Final Drives	1.1.7
		Control System	1.1.8
		Instrumentation and On Board Data Collection and Storage	1.1.9
	Systems Test & Evaluation (T&E)		1.2
		Static Systems Testing	1.2.1
		Dynamic System Testing	1.2.2
	Project Management		1.3
		Engineering Management	1.3.1
		Administrative Management	1.3.2
	Data		1.4
		Static Test Data	1.4.1
		Dynamic Test Data	1.4.2

WBS DEFINITIONS

1.0 HDSR Transmission

This element refers to the complex of equipment, data test and evaluation necessary to demonstrate HDSR in the M113 vehicle test bed. This element includes all the products and items associated with level 2 WBS elements.

1.1 HDSR System Hardware

This element refers to the entire hardware required to insure the successful demonstration of HDSR technology in the M113 vehicle ~~test~~ bed. This element also includes all effort associated with the development of the HDSR transmission system.

1.1.1 Integration and Assembly

This element refers to the effort of technical and support activities associated with the preparation and development of mating surfaces and interfaces, structures equipment, parts and other materials required to integrate and assemble the other functional level 3 component/equipment elements into the HDSR transmission system. It does not include those hardware items defined as being a part of other level 3 elements nor does it

include the effort required to integrate and assemble an individual level 3 component. This element also does not include the system/project management and system test and evaluation of the full up HDSR transmission system. The following efforts are also associated with this element:

(a) Component and subsystem receipt inspection.

(b) Set up, conduct and review of testing assembled components and subsystems prior to installation.

(c) Preparation of components and subsystems for installation in the M113.

(d) Instrumentation of components and subsystems.

(e) Interconnection of components and subsystems for their integration into the M113.

(f) Vehicle hull preparation prior to installation, cleaning and preparation of surfaces for corrosion and damage prevention.

(g) The joining, mating and final assembly of level 3 equipment/component elements to form a complete HDSR transmission system when performed by Rexroth.

(h) The conduct of contractor testing both static and dynamic.

1.1.2 Main System Pump

This element is associated with the primary source of hydraulic power for the HDSR. It includes only the main system pump and its associated electro hydraulic control gear, its fittings and mounting bracketry.

1.1.3 Auxiliary System Pumps

The auxiliary system element refers to the group of hydraulic pumps that provide hydraulic power for the control circuits, fan drive, gear changing and braking circuits and ramp drive; their associated electro hydraulic control gear, fittings, and mounting bracketry.

1.1.4 Pump Drive

This element refers to the 3 pad pump drive unit that provides for the mounting to the engine of the main system and auxiliary system hydraulic pumps. It includes its fittings; drain/fill/breathers and mounting bracketry.

1.1.5 Main Drive Motors

This element refers to the four (4) main drive motors. It includes the motors and the associated electro hydraulic control gear, fittings and mounting bracketry.

1.1.6 Auxiliary System Motors

This element refers to the three (3) auxiliary system motors, their electro hydraulic control gear, fittings, mounting bracketry and driven equipment, ie. fan assembly and stern ramp.

1.1.7 Final Drives

This element refers to the two (2) final drive units and all internal components and subsystems including parking brake and tacho generator. It includes all fittings, mounting bracketry and externally mounted control gear and maintenance equipment. Sprockets are also included in this element.

1.1.8 Control System

This element includes all electronic, electro hydraulic, hydraulic and mechanical control components and subsystems. It includes steering mechanisms, braking and gear changing mechanisms and cooling system mechanisms that are not associated directly to either final drives, pumps or motors, eg. manifolds, lines and fittings and intermediate hydraulic control devices. This element does not include any instrumentation and data storage/recording equipment.

1.1.9 Instrumentation and On-Board Data Collection and Storage

This element refers to all sensors and transducers and their associated hardware, on-board data recorders and power supplies. This element includes all instrumentation related equipment that is not directly associated with actual vehicle performance.

1.2 Systems Test and Evaluation (T&E)

This element refers to the use of all hardware to obtain and validate the performance of the HDSR transmission system. It also includes the conduct, support and data reduction of all operations concerned with T&E. It includes also the overall effort concerned with WBS units

1.2.1 and 1.2.2. It does not include testing described and included in 1.1.1.

1.2.1 Static System Testing

This element refers to all aspects of T&E when the M113 vehicle is static. It includes all testing effort that is associated with the hardware elements. It also includes all materials consumed in the process of static testing.

1.2.2 Dynamic System Testing

This element refers to all aspects of T&E when the M113

vehicle is in motion. It includes all testing concerned with overall vehicle performance in addition to the drive train. It also includes all materials consumed in dynamic testing.

1.3 Project Management

The project management element refers to the engineering and administrative control over the HDSR transmission system installation. The element includes the effort involved in managing technical control of the hardware installation and of WBS elements 1.1 and 1.2. Additionally it concerns the management of the development of logistic support policy and "trouble shooting" procedures for the HDSR.

1.3.1 Engineering Management

This element concerns the management of the HDSR hardware installation and includes development of final design layout and production of all data that refers to the actual HDSR installation and configuration. It also includes maintenance and accessibility aspects concerned with the repair and support of the transmission in the M113 vehicle. It includes development of policy and operational procedures, safety aspects and component

performance specifications resulting from actual test. This element includes the development of T&E support requirements in terms of contractor on site engineering support, spare/repair parts. It also includes any preparation of "as installed" data.

1.3.2 Administrative Management

This element refers to the business and administrative planning, organization, directing, coordinating, controlling and approval actions designated to accomplish overall project objectives that are not associated directly with specific hardware and T&E elements and engineering management. Examples of administrative management include:

(a) Cost scheduling.

(b) Resource allocation.

(c) Performance management.

(d) Contract management.

(e) Data management.

(f) Vendor liaison.

1.4 Data

This element refers to all data generated on the entire HDSR system. It does not include data produced

specifically from either static or dynamic testing.

1.4.1 Static Test Data

This element refers to data generated from all component, subsystem and systems T&E, acquired with the M113 vehicle and its components and subsystems static.

1.4.2 Dynamic Test Data

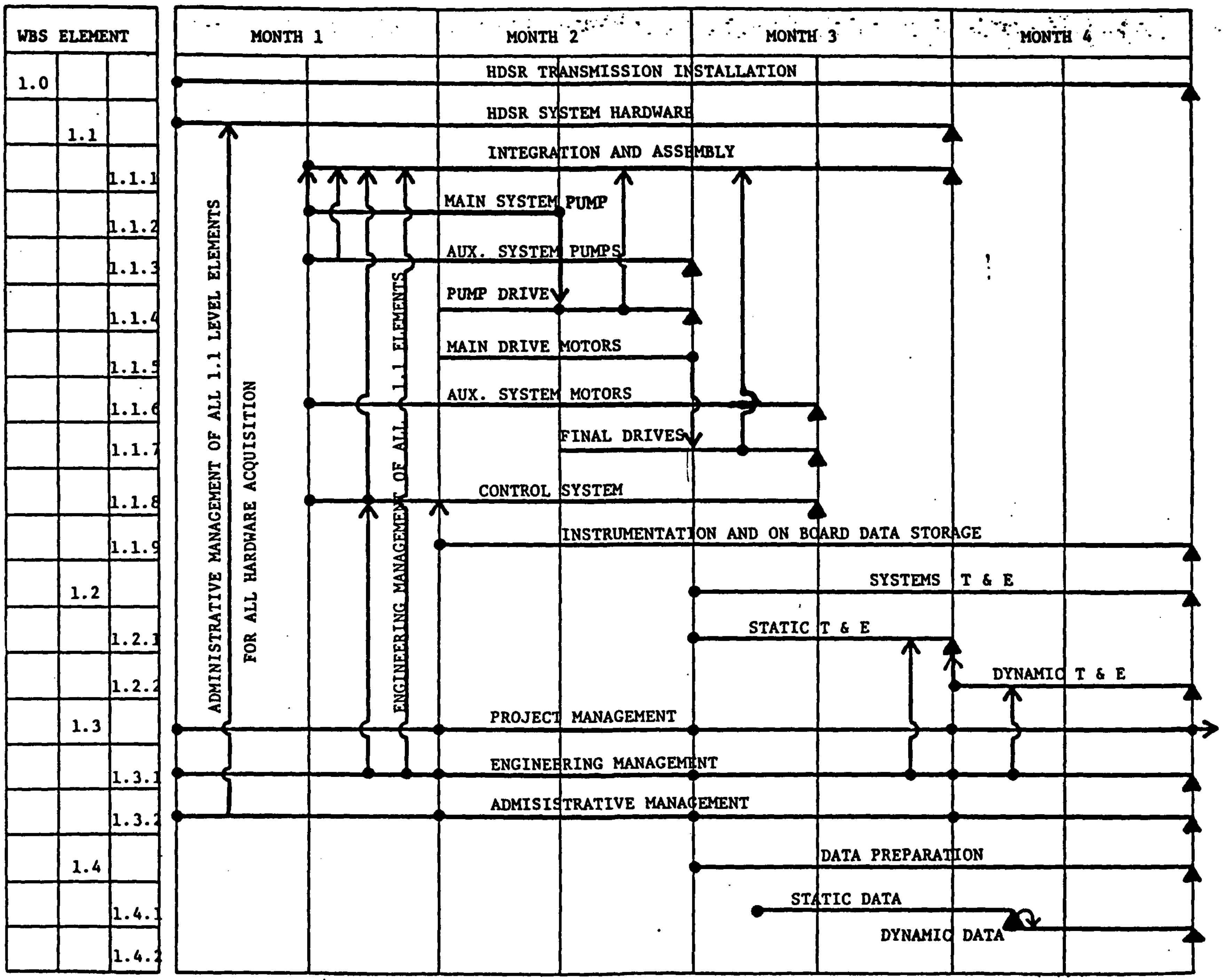
This element refers to data generated from all and transducers that generate on-board data that is stored and recorded on dynamic test equipment carried on, and self-contained in the M113 vehicle.

NOTES ON HDSR HARDWARE INSTALLATION

WORK BREAKDOWN STRUCTURE WITH PROGRAM SCHEDULE

1. Only the main events associated with HDSR installation have been shown. Interdependence is indicated by the vertical arrows, e.g. the final drive installation will have to be completed prior to main drive motor installation.

2. The chart should be read in conjunction with the WBS level layout and the WBS definitions.


WBS ELEMENT
1.0
1.1
1.1.1
1.1.2
1.1.3
1.1.4
1.1.5
1.1.6
1.1.7
1.1.8
1.1.9
1.2
1.2.1
1.2.2
1.3
1.3.1
1.3.2
1.4
1.4.1
1.4.2
MONTH 1
MONTH 2
MONTH 3
MONTH 4
HDSR TRANSMISSION INSTALLATION
HDSR SYSTEM HARDWARE
INTEGRATION AND ASSEMBLY
MAIN SYSTEM PUMP
AUX. SYSTEM PUMPS
PUMP DRIVE
MAIN DRIVE MOTORS
AUX. SYSTEM MOTORS
FINAL DRIVES
CONTROL SYSTEM
INSTRUMENTATION AND ON BOARD DATA STORAGE
SYSTEMS T & E
STATIC T & E
DYNAMIC T & E
PROJECT MANAGEMENT
ENGINEERING MANAGEMENT
ADMISISTRATIVE MANAGEMENT
DATA PREPARATION
STATIC DATA
DYNAMIC DATA
ADMINISTRATIVE MANAGEMENT OF ALL 1.1 LEVEL ELEMENTS
FOR ALL HARDWARE ACQUISITION
ENGINEERING MANAGEMENT OF ALL 1.1 ELEMENTS

13.0 Heat Balance

In the M113 with a HDSR transmission, heat within the engine/transmission compartment will be generated by the following:

- Engine waste heat.
- HDSR efficiency losses.
- Final drive efficiency losses.
- Fan drive efficiency losses.
- Auxiliary hydraulics efficiency losses.
- Radiated heat from all of the above.

All heat will be dissapated to the atmosphere through the main engine radiator and a single finned tube (mobile type) oil to air heat exchanger stacked in tandum and both supplied with the vehicle. Air flow for cooling is by a Noah Howden (Part No. Z6520-1) fan, also supplied with the vehicle. Fan speed is variable as a function of hydraulic oil and/or engine coolant temperature.

In this analysis, we assume that engine cooling is adequate and will match the worst case fan speed requirement for HDSR systems cooling. This may very well not be the case. We therefore plan to place temperature sensors in both the engine radiator top jacket and the main hydraulic reservoir. Whichever system temperature reaches its preset limit first will control fan speed.

Engine temperature will adjust fan speed to three levels based on engine coolant temperature.

- Below 180 degrees F the fan is stopped.
- Between 180 and 215 degrees F the fan speed is 1000 rpm*.
- Between 215 and 225 degrees F the fan speed is 2500 rpm*.
- Above 225 degrees F the fan speed is maximum*.

* Maximum fan speed will be determined by vehicle dynamic testing. All fan speeds may be adjusted based upon dynamic testing of the vehicle.

HDSR main system fluid will be maintained at 175 degrees F in the reservoir. This will provide 10 cs viscosity oil to the pump inlet for optimum HDSR efficiency. Fan drive fluid is common with main system fluid.

Final drive fluid is common with auxiliary hydraulics fluid. Heat generated by these components will be transferred to the engine coolant through a shell and tube heat exchanger. Engine coolant is selected for cooling these circuits for the following reasons:

- Engine coolant will be a 50/50 ethylene glycol/water solution which develops less pressure drop through a heat exchanger shell side than does hydraulic fluid at the same flow rates.
- Engine coolant flow rate is less than HDSR system flow which further reduces losses. (Approx. 10 gpm engine vs 20 gpm HDSR)
- Final drive units and auxiliary operating temperature can operate at engine temperature without penalties in efficiencies.

Summary of cooling requirements*

System	HP Loss	BTU/Min	Fluid	GPM	Fluid Temp. In	Temp. Out
HDSR	48	2036	Oil	15	190	175
Fan	5	212	Oil	2	190	175
Final Dr.	19	806	Oil	15	-	-
Other	1	424	Oil	Negli.	-	-
HDSR Total	53	2248	Oil	17	190	175

Ambient air in is estimated to be 125 degree F in the engine compartment.

* Worst case - see efficiency analysis

Heat Load = 2250 BTU/Min

$$\text{BTU/HR} \times 100 \text{ degree F/ITD} = \frac{2250 \times 100 \times 60}{190 - 125} = 210{,}000$$

From the attached curve for Model M-45, an air flow rate of 1750 FPM will provide needed cooling.

Required volumetric (Air) flow rate = (1750 CFM) (8.88) Ft)

= 15,540 CFM

Fan HP = 42 < 46 HP (See attached fan curve)

Summary:

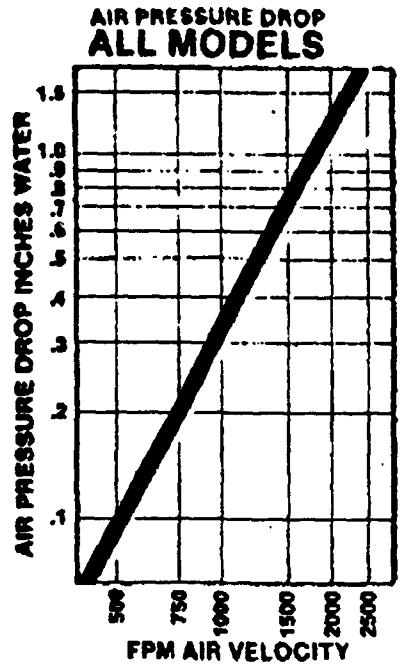
The worst case condition may be managed with the existing Noah-Howden fan at less than maximum (5000 rpm) speed. Under the worse case a

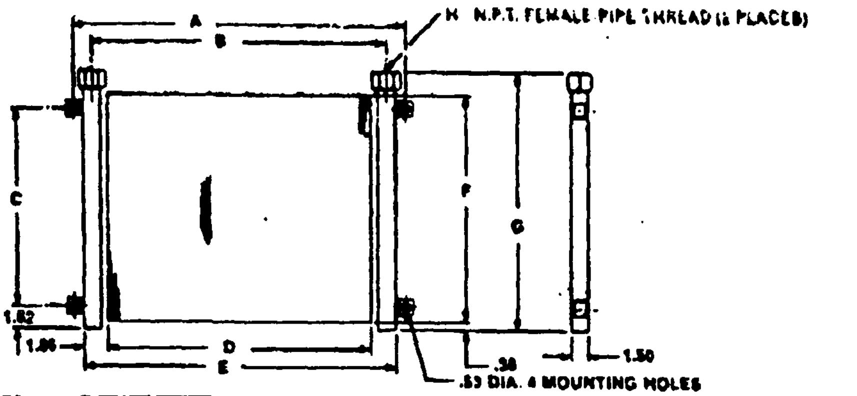
heat balance is achieved with the following conditions:

- Air flow rate: 15,540 CFM @ 4100 rpm fan speed
- Air pressure drop (In. H O): 1.0
- Air temperature In (Degree F): 125
- Oil temperature In (Degree F): 190
- Oil temperature Out (Degree F): 175
- Oil flow (gpm): 15

Heat rejection (BTU/MIN): 2250 = heat load of 2250

The M-45 air cooler data used in this analysis is manufactured by Thermal Transfer Products LTD., Racine, WI. This unit is similar in size and construction to the unit supplied with the vehicle. It is our intention to use the air cooler supplied with the vehicle on the basis of similarity. If this is not agreed with by DTNSRDC, a model M-45 will be installed.





Model	A	B	C	D	E	F	G	H	Face Area (Sq. Ft.)	Weight (Lbs.)
M-10	19.72	16.72	3.50	14.50	18.22	6.00	7.56	1	.60	6
M-15	19.72	16.72	5.50	14.50	18.22	8.00	9.56	1	.81	8
M-20	19.72	16.72	9.50	14.50	18.22	12.00	13.56	1	1.21	11
M-25	25.72	22.72	15.50	20.50	24.22	18.00	19.56	1	2.56	19
M-30	24.72	21.72	21.50	19.50	23.22	24.00	25.75	1¼	3.25	25
M-35	24.72	21.72	27.50	19.50	23.22	30.00	31.75	1¼	4.06	31
M-40	30.22	27.22	33.50	25.00	28.72	36.00	37.75	1¼	6.25	43
M-45	40.72	37.72	33.50	35.50	39.22	36.00	37.75	1¼	8.88	54

1. Calculate heat load to actually be dissipated:

   Horsepower x 2545 = BTU/Hour

   or

   BTU/Minute x 60 = BTU/Hour

2. Calculate heat load for use with curves. Curves are based on 100°F ITD (initial temperature difference) between entering oil and ambient air.

   $$\frac{\text{BTU/Hour} \times 100°\text{F}}{(°\text{F oil entering} - °\text{F Ambient air})} = \text{BTU/Hour} \times \frac{100°\text{F}}{\text{ITD}}$$

3. Calculate air velocity or CFM (cubic feet per minute) required (assume a face area from table):

   $$\text{FPM (feet per minute) velocity} = \frac{\text{CFM}}{(\text{square feet face area})}$$

   or

   CFM = (FPM velocity) x (square feet face area)

   Face area must be consistent with model used.

4. To find the model number of cooler enter bottom of curve with GPM oil flow, go upward to FPM air velocity, then left to BTU/Hour x 100°F ITD value calculated from step 2.

5. To find oil pressure drop start at bottom of curve with GPM oil flow, go upward to average oil viscosity (see Viscosity Table), then right to oil pressure drop.

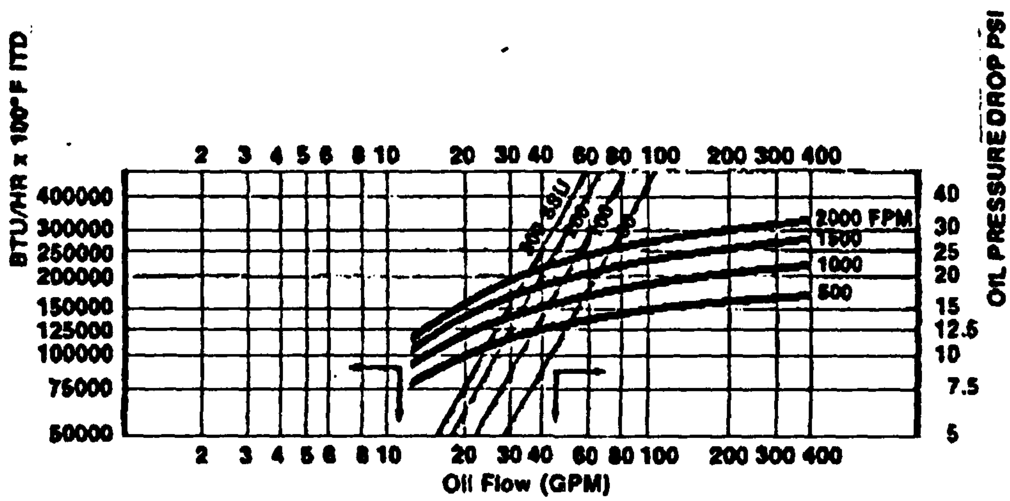
EXAMPLE:
With 40,000 BTU/Hour heat to be dissipated at 40 GPM oil flow of SAE 10 oil at 180°F entering and 2560 CFM of air at 100°F ambient, determine cooler model number and oil pressure drop.

A. $\frac{40{,}000 \text{ BTU/Hour} \times 100°\text{F}}{180°\text{F} - 100°\text{F}} = 50{,}000 \text{ BTU/Hour} \times \frac{100°\text{F}}{\text{ITD}}$

B. $\frac{2560 \text{ CFM}}{2.56 \text{ Face Area}} = 1000 \text{ FPM air velocity}$

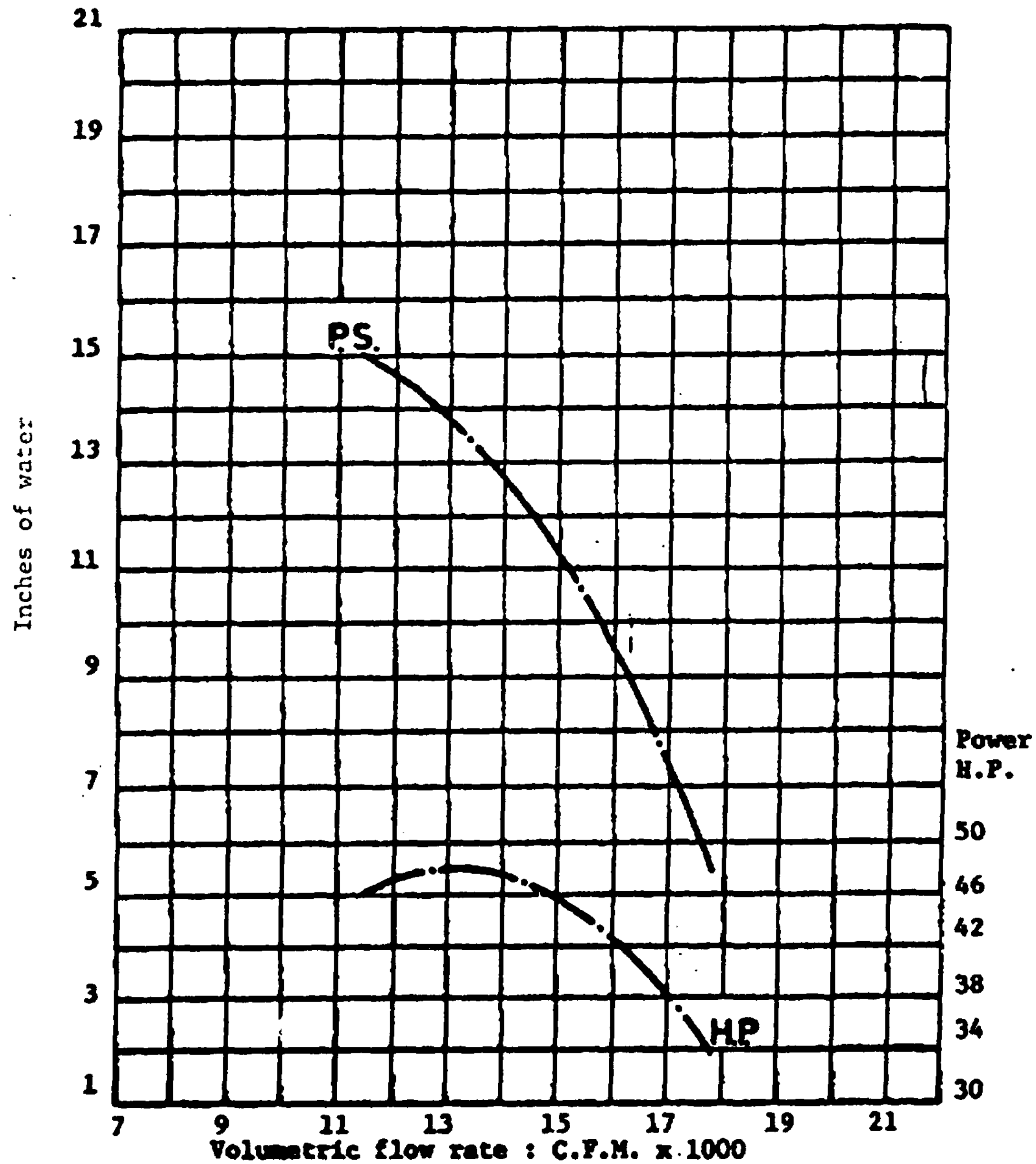
Model M-25 is selected from the curve because at 40 GPM oil and 1000 FPM air velocity BTU/Hour x 100°F ITD = 55,000. Oil pressure drop at 40 GPM oil and 50 SSU oil viscosity is 13 PSI.

Oil Temp. °F	OIL VISCOSITY, SSU				
	SAE 5	SAE 10	SAE 20	SAE 30	SAE 40
100	110	150	275	500	750
210	40	43	50	65	75



M-45

All dimensions in inches.
NOTE: Thermal Transfer Products, Ltd., reserves the right to make reasonable design changes without notice.



Customer: Rexroth
Date: 08/20/86

Specified data -
Fan speed: 5000 rpm
Inlet density: .075 lb/ft. 3

Standard data -
Fan type: Axial
Part #: 26520-1
Nominal supply: Direct Drive
Impeller dia.: 20 Inches
Nominal weight: 90 lbs.
Fan speed: 4500 rpm

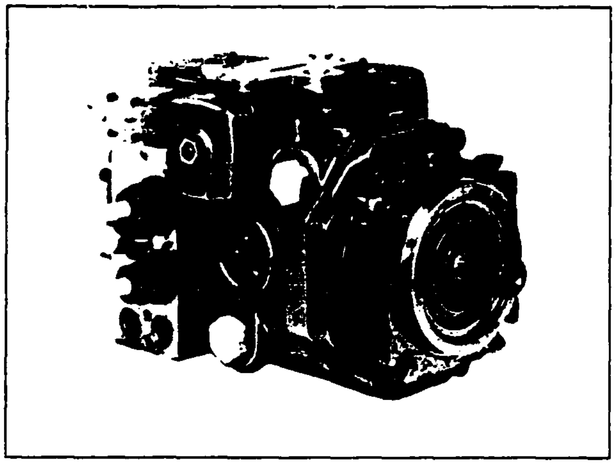
Appendix 1

REXROTH
WORLDWIDE HYDRAULICS
MOBILE HYDRAULICS DIVISION
1700 Old Mansfield Rd.
P.O. Box 394 Wooster, OH 44691
216/263-3300 Telex: 98-6335
INDUSTRIAL HYDRAULICS DIVISION
2315 City Line Rd.
P.O. Box 2407 Bethlehem, Pa. 18018
215/694-8300 Telex: 84-7496

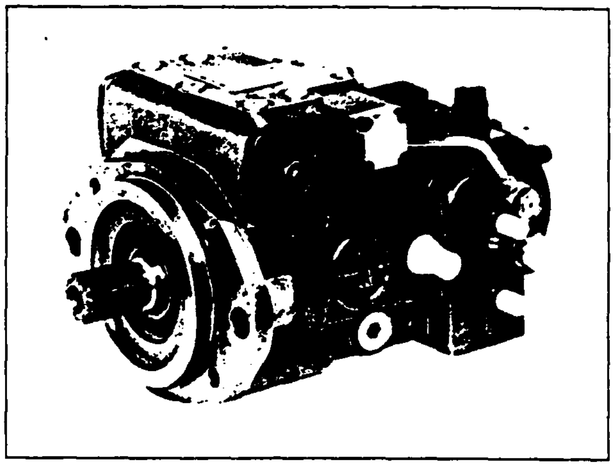
HYDROSTATIC TRANSMISSION
Type AA4V Pump—Type AA6V Motor
Gas Pedal (Automotive) Control (DA)
Speed Sensing Option for Displacement Controls

RA 06202
Replaces RA 13342

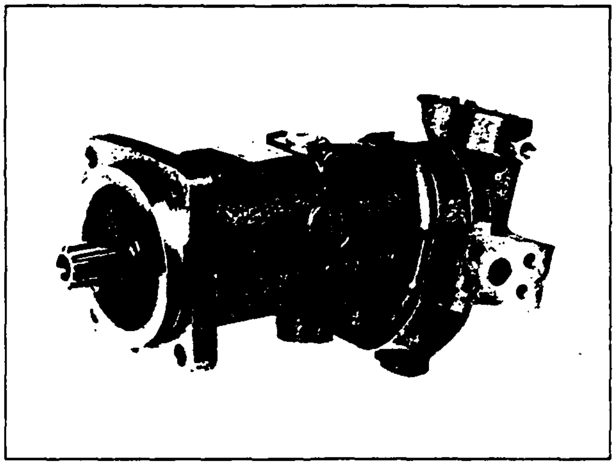
Sizes 40–250	Up to 6000 psi	2.44 to 15.25 in³/rev.	Issue Date: 10/84



AA4V 71, 250 Series 2



AA4V 40, 56, 90, 125 Series 1



AA6V 55, 107, 160 Series 2

Description: AA4V

The AA4V is a swashplate design, variable displacement, over center, axial piston pump that has been designed exclusively for closed circuit hydrostatic transmissions where a self-contained pump package is required.

The pump design incorporates a charge pump, charge pressure relief valve, and two combination high pressure relief and make-up check valves. SAE A, B, B-B and C through drives are also available as an option on the AA4V.

Description: AA6V

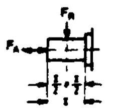
The AA6V variable displacement axial piston motors are designed for use in hydrostatic transmissions when both high torque and high speed are required. They may be used in open and closed circuits, with or without charge pressure on the outlet port.

Features

- High power to weight ratio
- High volumetric efficiency due to the spherical control plate
- Heavy duty service capability
- SAE high pressure and threaded ports
- "State of the art" design
- Compact size and lightweight
- Low noise levels
- High strength cast iron housing
- SAE mtg. flange and spline shaft
- High shaft loading capability
- High starting torque characteristics of the AA6V motors

Technical Details

General Specifications AA4V Pump

Specifications	Unit	AA4V40	AA4V56	AA4V71	AA4V90	AA4V125	AA4V250*
Displacement	in³/rev	2.44	3.42	4.33	5.49	7.63	15.25
	cm³/rev	40	56	71	90	125	250
Nominal flow at 1000 rpm	gpm	10.56	14.80	18.74	23.77	33.00	66.02
	l/min	40	56	71	90	125	250
Maximum pressure	psi	6000	6000	6500	6000	6000	6500
	bar	414	414	448	414	414	448
Torque constant	lb ft/100 psi	3.23	4.53	5.74	7.28	10.12	20.22
	Nm/bar	0.636	0.89	1.13	1.44	1.98	3.97
Maximum allowable shaft torque	lb ft	305	381	451	473	1007	1255
	Nm	414	517	611	641	1367	1702
Maximum drive speed	rpm	3700	3400	3200	2900	2600	2000
Minimum drive speed	rpm	500	500	500	500	500	500
Weight (approx., varies with control type)	lbs	64	77	95	112	154	287
	Kg	29	35	43	51	70	130
Moment of inertia	lb in²	16.72	29.01	41.34	59.73	102.4	327.7
	Kgm²	0.0049	0.0085	0.0121	0.0175	0.03	0.0959
Maximum case pressure	psi	29	29	29	29	29	29
	bar	2	2	2	2	2	2
Maximum permissible external loading of the drive shaft 	F_A lbs	337	494	617	786	1078	1349
	N	1500	2200	2750	3500	4800	6000
	F_B lb	809	1124	1416	1798	2472	4946
	N	3600	5000	6300	8000	11000	22000

*The 250 DA control is not normally stocked and longer lead times will apply.

Charge Pump

	Unit	AA4V40	AA4V56	AA4V71	AA4V90	AA4V125	AA4V250
Displacement	in³/rev	0.51	0.70	1.16	1.16	1.61	3.20
	cm³/rev	8.4	11.4	19.0	19.0	26.4	52.5
Nominal flow at 1000 rpm	gpm	2.20	3.03	4.00	5.02	6.97	13.85
	l/min	8.4	11.4	15.1	19.0	26.4	52.5
Nominal pressure	psi	320	320	320	320	320	320
	bar	22	22	22	22	22	22
Maximum pressure	psi	580	580	580	580	580	580
	bar	40	40	40	40	40	40
Minimum inlet pressure (at normal operating temperature)	psig	−3.2	−3.2	−3.2	−3.2	−3.2	−3.2
	bar (absolute)	0.8	0.8	0.8	0.8	0.8	0.8

Description... The AA4V is a swashplate design, variable displacement, over center, axial piston pump manufactured by the Hydromatik Division of Rexroth.

The AA4V has been designed exclusively for closed circuit hydrostatic transmissions where a self-contained pump package is required. The pump design incorporates a charge pump, a charge pressure relief valve, and two combination high pressure relief and make-up check valves.

The control options are of modular design to allow interchangeability without altering the basic pump. The three basic displacement controls are:

remote hydraulic pilot	(type HD)
manual rotary servo	(type HW)
proportional electric	(type EL)

A complete range of control accessories is available to extend the control versatility of this pump.

Installation... The AA4V pump may pe mounted in any position around the horizontal axis. The horizontal axis (drive shaft) may be tilted 15° in either direction from the horizontal.

The AA4V transmission pump is usually face mounted to a drive gear box with the shaft engaging a mating female splined gear hub, or spline adapter. The large drive shaft bearings permit the pump to be driven by vee or toothed belt drives. The case drain line should be connected to the highest case drain port (T_1, T_2, T_3 or T_4) so that the pump case always remains full of oil. The case drain return piping, or hose, should be sized to accept the full flow of the charge pump at the maximum anticipated drive speed.

For mobile applications, the oil reservoir capacity required (in US gallons) is generally .75 to 1 times the charge pump flow (in US gallons per minute) for a one pump, one motor transmission. The heat exchanger should be located between the pump case drain and the reservoir, and sized to accept the full flow of the charge pump at the maximum anticipated drive speed.

Fluid Recommendations... The AA4V pumps are supplied as standard for use with good quality, petroleum based hydraulic fluids.

The prime consideration in the selection of a hydraulic fluid, is the expected oil temperature extremes that will be experienced in service. These extremes will govern the selection of a fluid with the most suitable temperature-viscosity characteristics.

When there is a question of the suitability of a particular fluid, or for applications which will operate near the extremes of viscosity or temperature, the fluid manufacturer should be consulted.

Viscosity Ranges... The hydraulic fluid selected should operate with the following viscosity ranges.

Maximum viscosity at start-up	4600 SSU	(1000 cSt)
Normal operating viscosity range	66-464 SSU	(12-100 cSt)
Optimum viscosity range	81-141 SSU	(16-30 cSt)
Absolute minimum viscosity	60 SSU	(10 cSt)

Operating Temperature... −13°F to +195°F (−25°C to +90°C).

The temperature level of a particular system is normally measured at the pump or motor case drain. This temperature is then used to establish the cooling requirements for the system.

Start-Up... The pump case must be filled with oil, and where possible, all piping and hoses should be filled with oil prior to the first start-up.

The pump control should be set at zero stroke for start-up.

Before running the pump at full speed the drive should be jogged until a charge pressure of at least 50 psi is established.

Applications vary and therefore the most suitable start-up method should be selected for the application.

MORE DETAILED INFORMATION ON MOUNTING POSITION, INSTALLATION, FILTRATION, FLUIDS AND START-UP PROCEDURES, IS AVAILABLE IN A SEPARATE PUBLICATION TITLED 'AA4V APPLICATION AND SERVICE MANUAL.'

Technical Details

General Specifications AA6V Variable Motor

Specifications	Units	AA6V55	AA6V107	AA6V160
Maximum displacement (V_{max})	in³/rev	3.34	6.53	9.76
	cm³/rev	54.8	107	160
Minimum displacement (V_{min})	in³/rev	.96	1.88	2.81
	cm³/rev	15.8	30.8	46
Maximum speed at V_{max}	rpm	3750	3000	2650
Maximum speed at V_{min}***	rpm	5000	4000	3500
Maximum pressure	psi	5800	5800	5800
	bar	400	400	400
Torque constant (at V_{max})	lb ft/100 psi	4.43	8.66	12.94
	Nm/bar	0.870	1.697	2.541
Torque constant (at V_{min})	lb ft/100 psi	1.27	2.49	3.73
	Nm/bar	0.249	0.488	0.732
Maximum allowable shaft torque (at 6000 psi)	lb ft	265	520	776
	Nm	359	705	1051
Weight (varies with control)	lb	60	114	163
	Kg	27	52	74
Moment of inertia	lb-in²	17.75	57.00	110.0
	Kg-m²	0.0052	0.0167	0.0322
Maximum case pressure	psig	29	29	29
	bar (positive)	2	2	2

***See chart on page 15 for maximum speeds at intermediate displacements.

Description... The AA6V variable displacement axial piston motors feature the bent-axis design rotary group, which provides high starting torque and high operating speeds. The bent-axis rotary group utilizes a spherical control plate, which allows the ports to be located close to the center line, reducing the relative fluid velocity as it enters and exits the cylinders, thus improving the cylinder filling characteristics. In addition, the spherical control plate improves volumetric efficiency at high pressures.

The stroking action is to one side of center only, hence the physical size and weight is less than most variable displacement axial piston motors currently available.

The motor displacement may be changed while driving under full load, and actuation of the motor control allows the cylinder block to swivel between maximum and minimum displacements to give a speed ratio of up to 3.47:1. Six control variations for manual or automatic operation are available for the AA6V motor.

Mounting Position... The AA6V motor may be mounted in any position. When mounting in a shaft-up position, special considerations regarding the case drain line are required to ensure the motor bearings are always immersed in oil.

Installation... The AA6V is usually face mounted to a final drive gear box with the shaft engaging a mating female splined gear hub or spline adapter. The large drive shaft bearings permit vee or toothed belt pulleys, and gear pinions to be mounted directly to the drive shaft. The motor may also be used to transmit power via a universal drive shaft.

The case drain line should be connected to the highest case drain port so that the motor always remains full of oil.

Fluid Recommendations... The AA6V motors are supplied as standard for use with good quality, petroleum based hydraulic fluids.

The prime consideration in the selection of hydraulic fluid is the oil temperature extremes that will be experienced in service. These extremes will govern the selection of a fluid with the most suitable temperature-viscosity characteristics.

When there is a question of the suitability of a particular fluid, or for applications which will operate near the extremes of viscosity or temperature, the fluid manufacturer should be consulted.

The AA6V may be operated with certain synthetic or water-oil fluids. Please contact Rexroth for details.

Viscosity Ranges... The hydraulic fluid selected should operate within the following viscosity ranges.

Maximum viscosity at start-up	4600 SSU	(1000 cSt)
Normal operating viscosity range	66-464 SSU	(12-100 cSt)
Optimum viscosity range	81-141 SSU	(16-30 cSt)
Minimum viscosity	60 SSU	(10 cSt)

Operating Temperature... −13°F to +195°F (−25°C to +90°C).

The temperature level of a particular system is normally measured at the pump or motor case drain. This temperature is then used to establish the cooling requirements for the system.

Start-Up... The motor case must be filled with oil, and where possible, all piping and hoses should be filled with oil prior to the first start-up. The pump control should be set at zero stroke for start-up. Before running the motor at full speed, the variable pump, or directional valve, should be operated to provide 10-20% flow until all lines have been filled, and motor control operation has been checked. Applications vary, therefore, the most suitable start up method should be selected for the application.

Filtration

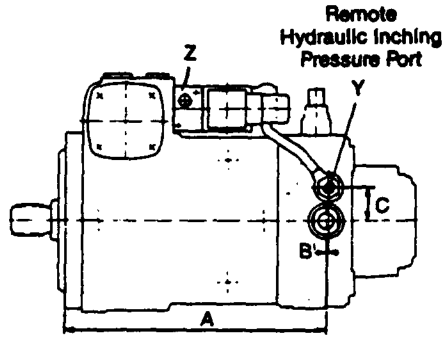
The fluid should be filtered prior to system start-up, and continuously during operation, to achieve and maintain a cleanliness level of ISO 18/15. (This corresponds approximately to NAS 1638 Class 9, or SAE [1963] Class 6.) This recommendation should be considered a minimum, as better cleanliness levels will significantly increase component life.

Each application should be analyzed to determine the proper method of filtration needed to maintain the required cleanliness levels, as contaminant generation and ingresssion can vary greatly, depending on the configuration and complexity of the system.

For particular system requirements, or for application outside these parameters, a Rexroth Applications Engineer should be consulted.

See page 12 of this brochure for details of the three available filtration methods.

Installation Dimensions

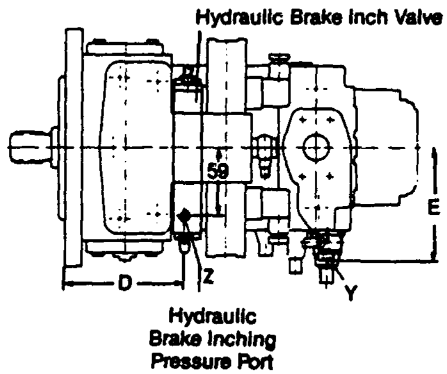


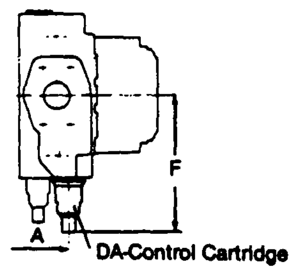
Pump Size

	A	B	C	D	E	F
40	8.51	.06	1.10	3.60	5.24	3.70
	216.1	1.5	28.0	91.5	133.0	94.0
56	9.1	.06	1.10	3.97	5.24	3.70
	231.2	1.5	28.0	100.8	133.0	94.0
90	10.30	.22	1.24	4.51	5.12	4.09
	262.5	5.5	31.5	114.5	130.0	104.0
125	11.59	.47	1.61	5.06	5.39	4.70
	294.5	12.0	41.0	128.5	136.8	119.5

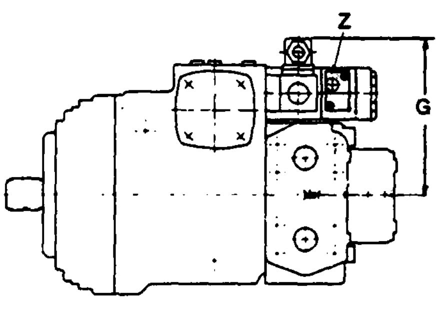
Shaded Dimensions are in Millimeters

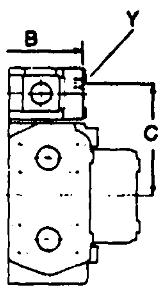
Port Size
Y, – 4 JIC 37° Flare
Z, Consult Rexroth on size and availability.





FOR FURTHER DIMENSIONS, REFER TO RA06200



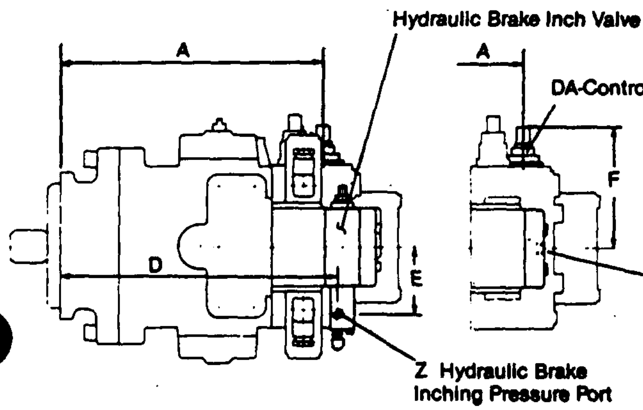


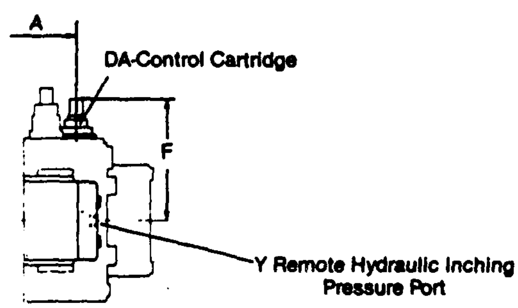
Pump Size

	A	B	C	D	E	F	G
71	10.37	11.16	4.43	10.98	2.68	5.16	6.07
	263.5	283.5	112.5	279.0	68.0	131.0	154.2
250	Consult Rexroth for dimensions						

Shaded Dimensions are in Millimeters

Port Size
Y, – 4 JIC 37° Flare
Z, Consult Rexroth on size and availability.



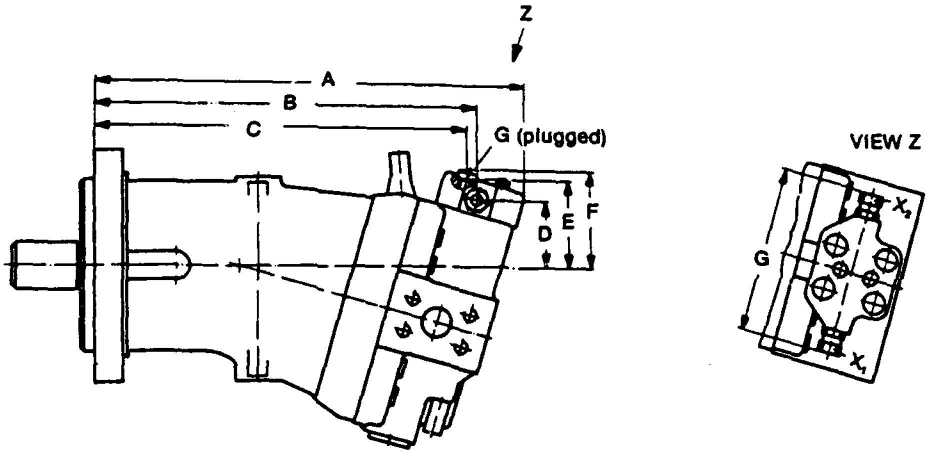


FOR FURTHER DIMENSIONS, REFER TO RA06210

Installation Dimensions

Please ask for confirmation of important dimensions prior to determining your final design.

VARIABLE DISPLACEMENT MOTOR AA6V
Engine Speed Related Control, Type DA
Port G, M14 x 1.5



Motor Size

	A	B	C	D	E	F	G
55	13.13	11.36	11.20	1.93	2.75	3.03	5.75
	333.5	288.5	284.5	49.0	69.9	77.0	146.1
107	16.22	14.49	14.33	2.32	3.19	3.46	5.98
	412.0	368.0	364.0	58.9	81.0	87.9	151.9
160	18.66	16.50	16.34	2.56	3.38	3.70	6.22
	474.0	419.1	415.0	65.0	85.9	94.0	158.0

Shaded Dimensions are in Millimeters

FOR FURTHER DIMENSIONS, REFER TO RA06160

Motor Speed/Displacement Limitations

MAXIMUM SPEED... The maximum shaft speeds of the AA6V variable displacement motors, when operated at reduced displacements, are listed in the following table. The speeds given are maximums when operating with swivel angles between 18.5° and 7°.

Motor Size	55	107	160
Maximum speed At Vmax (25°)	3750	3000	2650
Maximum speed at reduced displacement (18.5° to 7° swivel angle)	5000	4000	3500
Maximum permissible flow Qmax in gpm	54.2	84.4	111

DESIGN SPEED... When designing a hydrostatic transmission for a vehicle or winch drive using these motors, we recommend a design speed of approximately 85% of the maximum speed at the reduced displacement. This allows for hydraulic motor speeds up to the maximum when traveling downhill, or when lowering the load on a hydrostatic winch drive. It is also necessary to consider the "high idle" engine speeds and improved volumetric efficiencies of the hydraulic pump and motor when the hydrostatic transmission is lightly loaded.

APPLICATION ASSISTANCE... If your application calls for design and maximum speeds in excess of the above limits, please contact a Rexroth Application Engineer so that the application parameters can be reviewed and, if appropriate, an approval to exceed the maximums can be granted.

Appendix 2

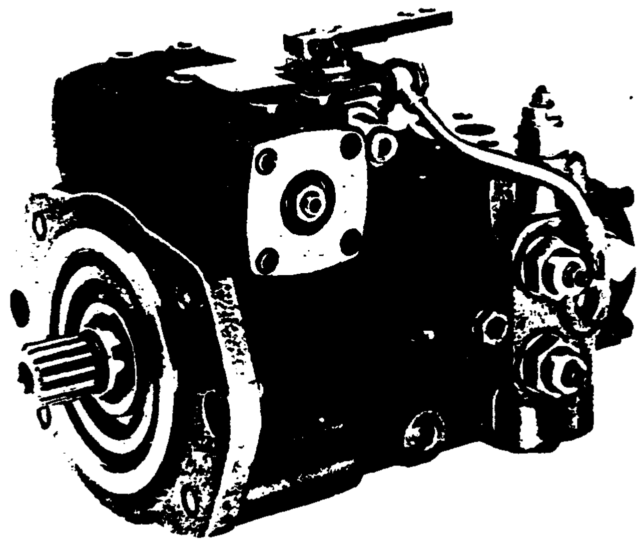
REXROTH
WORLDWIDE HYDRAULICS

MOBILE HYDRAULICS DIVISION
1700 Old Mansfield Rd.
P.O. Box 394 Wooster, OH 44691
216/263-3400 Telex: 98-6335
INDUSTRIAL HYDRAULICS DIVISION
2315 City Line Rd.
P.O. Box 2407 Bethlehem, Pa. 18018
215/694-8300 Telex: 84-7496

HYDROSTATIC TRANSMISSION PUMP TYPE AA4V Controls HD, HW, EL, OV, & HM

RA 06200

Sizes 40 to 125	Up to 6000 psi	2.44 to 7.63 in³/rev.	Issue Date: 1/86



Description

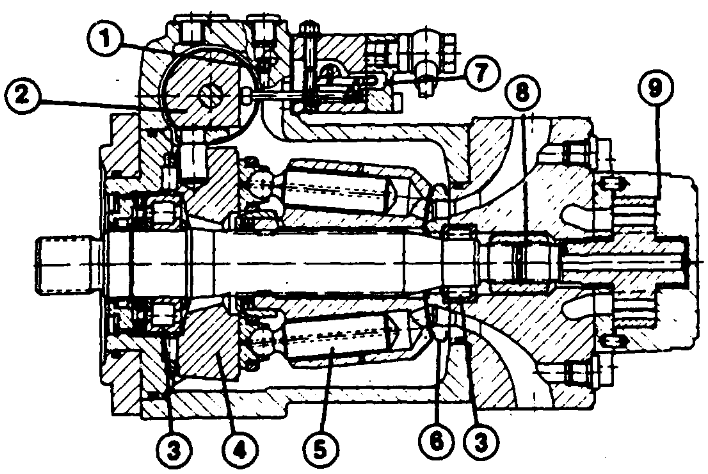
The AA4V is a swashplate design, variable displacement, over center, axial piston pump that has been designed exclusively for closed circuit hydrostatic transmissions where a self-contained pump package is required.

The pump design incorporates a charge pump, a charge pressure relief valve, and two combination high pressure relief and make-up check valves.

Features

- High power to weight ratio
- High volumetric efficiency due to the spherical control plate.
- Heavy duty service capability
- "State of the art" design
- Compact size
- Lightweight
- Low noise levels
- SAE mounting flange and spline shaft
- SAE high pressure and threaded ports
- High strength cast iron housing
- Many control options available

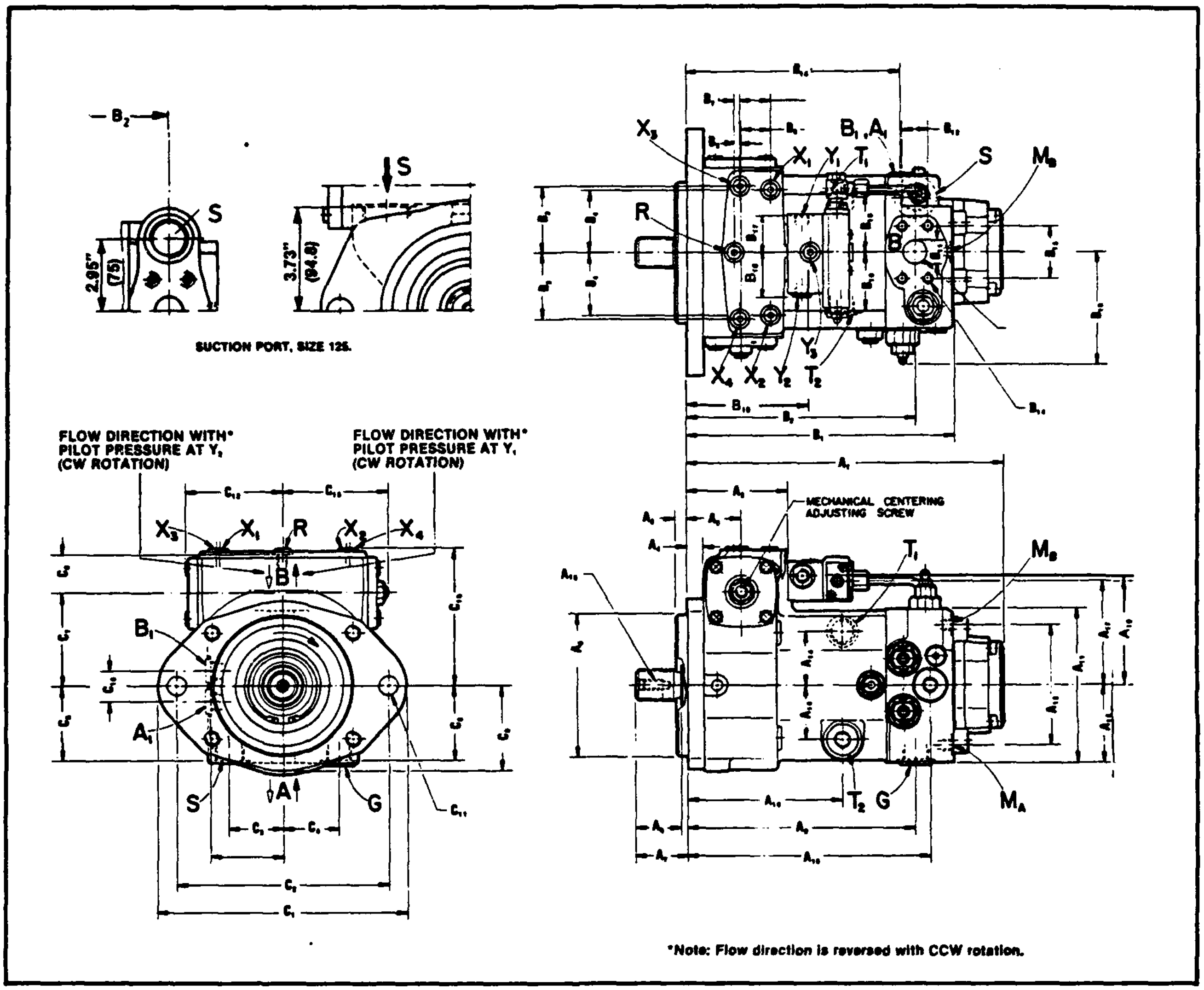
Construction



1 Stroking time orifice (2 per pump)
2 Control piston
3 Heavy duty roller bearings
4 Rocker cam swashplate
5 Inclined pistons
6 Spherical control plate
7 Control module
8 Spline coupling
9 Internal gear charge pump

Installation Dimensions

Pump Sizes 40, 56, 90 and 125 With HM Control



*Note: Flow direction is reversed with CCW rotation.

Size	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	A_{17}	A_{18}	A_{19}	B_8	B_9	B_{10}	B_{11}	B_{12}
40	11.22	3.31	1.81	0.51	1.89	5.00	2.20	0.49	7.82	5.00	5.39	2.70	4.57	1.85	—	8.51	3.54	7/16-14	3.80	4.07	2.58	1.95	0.75	0.94
	285	84	46	13	48	127	56	12.5	198.6	127.1	137	68.5	116	47	—	216.1	89.8	UNC-2B	96.5	103.4	65.5	49.5	19	23.8
56	12.05	3.67	2.05	0.59	1.89	5.00	2.20	0.49	8.41	5.60	5.98	2.99	4.57	2.15	—	9.10	3.88	7/16-14	4.14	4.44	2.58	2.07	0.75	0.94
	306	93.3	52	15	48	127	56	12.5	213.7	142.2	152	76	116	54.5	—	231.2	98.5	UNC-2B	105.2	112.7	65.5	52.5	19	23.8
90	13.39	4.21	2.28	0.67	1.89	6.00	2.20	0.49	9.65	6.57	6.50	3.25	5.12	2.32	—	10.33	4.43	7/16-14	4.69	4.98	2.58	2.44	0.98	1.09
	340	107	58	17	48	152.4	56	12.5	245	167	165	82.5	130	59	—	262.5	112.5	UNC-2B	119.1	126.4	65.5	62	25	27.8
125	15.37	4.76	2.58	0.79	2.64	6.00	2.44	0.49	10.73	7.19	7.48	3.74	5.91	2.60	0.16	11.59	4.86	5/8-11	5.12	5.53	2.58	2.68	1.26	1.25
	390.5	121	65.5	20	67	152.4	62	12.5	272.5	182.5	190	95	150	66	4	294.5	123.5	UNC-2B	130.0	140.4	65.5	68	32	31.8

Size	B_{13}	B_{14}	B_{15}	B_{16}	B_{17}	B_{18}	B_{19}	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{16}	C_{18}
40	2.00	3/8-16 UNC	4.26	7.41	1.54	1.97	4.05	8.39	7.13	2.05	2.09	2.50	2.68	3.10	1.44	2.80	4.70	0.69	3.37	3.50	1.34	2.48
	50.8	0.63 DEEP	108.2	188.1	39.1	50.0	102.9	213	181	52	53	63.5	68	78.8	36.5	71	119.3	17.5	85.6	89	34	63
56	2.00	3/8-16 UNC	4.26	8.00	1.54	1.97	4.39	8.39	7.13	2.05	2.09	2.81	2.80	3.44	1.50	3.07	5.12	0.69	3.61	3.74	1.34	2.68
	50.8	0.63 DEEP	108.2	203.2	39.1	50.0	111.5	213	181	52	53	71.5	71	87.5	38	78	130	17.5	91.6	95	34	68
90	2.25	7/16-14 UNC	4.74	9.06	1.54	1.97	4.94	10.51	9.00	2.32	2.36	3.09	3.09	4.00	1.67	3.54	5.87	0.81	4.08	4.41	1.34	3.07
	57.2	0.63 DEEP	120.5	230	39.1	50.0	125.5	267	228.6	59	60	78.5	78.5	101.5	42.5	90	149	20.6	103.6	112	34	78
125	2.63	1/2-13 UNC	5.22	9.98	1.54	1.97	5.37	10.51	9.00	—	2.68	3.54	—	4.43	1.81	3.84	6.44	0.81	4.88	5.12	1.42	3.60
	66.7	0.82 DEEP	132.5	253.5	39.1	50.0	136.4	267	228.6	—	68	90	—	112.5	46	97.5	163.5	20.6	124	130	36	91.5

Weights: 40 — 64 lbs. / 29 kg; 56 — 77 lbs. / 35 kg; 90 — 112 lbs. / 51 kg; 125 — 154 lbs. / 70 kg

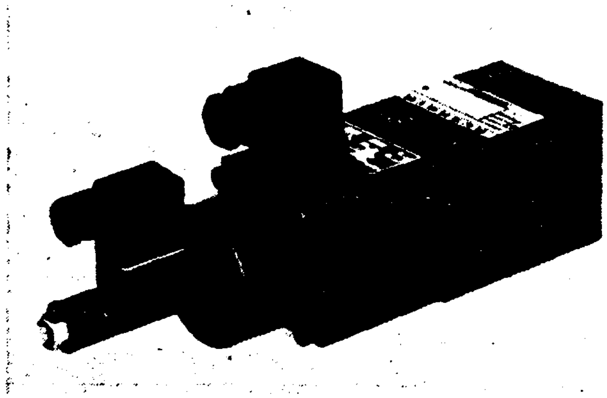
Note: See page 2 for spline data

Shaded dimensions are in millimeters.

Appendix 3

MANNESMANN REXROTH	Proportional Pressure Relief Valve Type DBETR/Series 1X			RE 29 166/8.86
	Size 6	max. 25, 180 and 315 bar	2, 3 and 10 L/min	Replaces: 7.84

- low hysteresis
- good repeatability
- electrical feedback of the set spring tension
- proportional solenoid with inductive positional transducer (pressure balanced)
- mounting dimensions to DIN 24 340 Form A 6



Type DBETR-1X/...

Description of Function, Section

Proportional pressure relief valves type DBETR are direct operated, seated type valves with electrical remote control.

The pressure setting of the valve is directly proportional to the electrical input signal.

The valve basically consists of the body (1), the proportional solenoid (2) complete with inductive positional transducer (3), valve seat (4) and valve poppet (5).

The input signal for the pressure setting is given by an input potentiometer (0 – 9 V). This input signal operates via amplifier type VT-5003 and the proportional solenoid (2) to compression spring (6). The tension in the spring (6), i.e. the actual position of the pressure pad (7), is determined by the positional transducer (3). Any difference between this and the input value is then corrected by the control system.

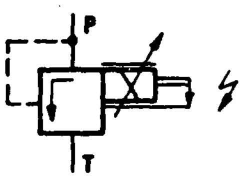
Using this principle, the solenoid friction is overcome.

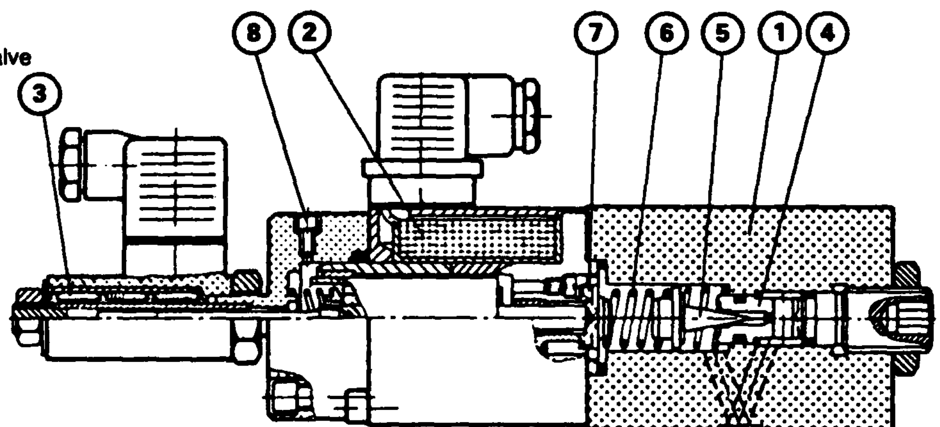
This gives: low hysteresis,
good repeatability.

With a zero input signal, loss of current to the proportional solenoid, or break in the cable to the positional transducer, the valve automatically sets to the lowest pressure.

Important:
When commissioning, bleed valve via bleed screws (8).

Symbol





Type DBETR-1X/...

Ordering Code

DBETR – 1X / [ ] [ ] *

Series 10 to 19 (10 to 19 ≙ installation and connection dimensions remain unchanged)	= 1X
Pressure stage:	
up to 25 bar	= 25
up to 180 bar	= 180
up to 315 bar	= 315
no desig. =	mineral oils DIN 51 524 (HL, HLP)
V =	phosphate ester (HFD-R)
Further details in clear text	

Technical Data (For applications outside these parameters, please consult us!)

Hydraulic

Max. pressure setting	– pressure stage 25	bar	..25
	– pressure stage 180	bar	..180
	– pressure stage 315	bar	..315
Min. pressure setting (volume dependent)			(see curves on page 3)
Port T			separately to tank
Max. pressure in port T	with pressure regulation	bar	..2
	without pressure regulation port T locked	bar	..315
Max. pressure in port P		bar	..315
Max. flow	– pressure stage 25	L/min	..10
	– pressure stage 180	L/min	..3
	– pressure stage 315	L/min	..2
Filtration		µm	< 25 required (< 10 µm recommended for increased life)
Fluid			mineral oils DIN 51 524 (HL, HLP) phosphate ester (HFD-R)
Fluid temperature range		°C	– 20 ... + 70
Viscosity range		mm^2/s	2,8 ... 380
Hysteresis		%	< 1 of max. pressure setting
Repeatability		%	< 0,5 of max. pressure setting
Linearity – pressure stage 180 (between 30 and 180 bar)	– pressure stage 315 (between 60 and 315 bar)	%	< 1,5 of max. pressure setting
Typical variation	DBETR	%	± 3 of max. pressure setting
	amplifier type VT-5003	%	< 0,5

	Stepped Input %	$p_{min} - p_{max}$ Tu + Tg ms Response time	$p_{max} - p_{min}$ Tu + Tg ms Response time
Pressure stage 25 and 180	0 ... 100	100	50
Pressure stage 315	0 ... 100	150	100

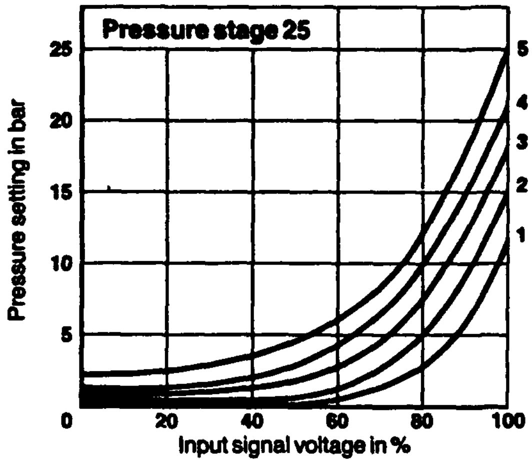
Mounting position		Optional
Weight	kg	4,0

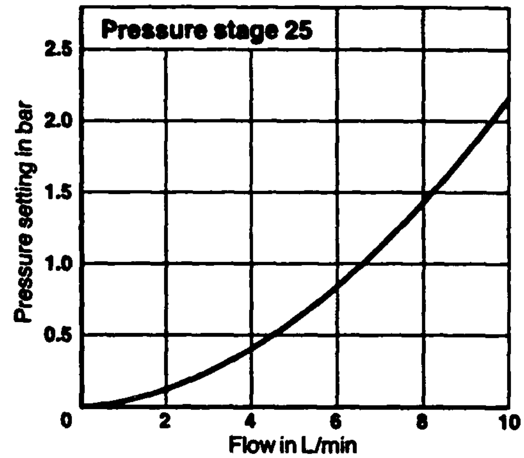
Electrical

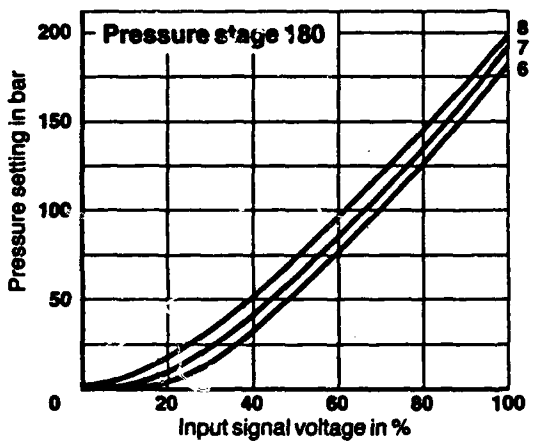
Type of supply			DC
Solenoid coil resistanc	cold at 20 °C	Ω	10
	max. warm value	Ω	13,9
Duty		%	Continuous
Max. ambient temperature		°C	... + 50
Electrical connections	solenoid		Plug and socket to DIN 43 650/2 pole + SL/PG 11
	positional transducer		Plug and socket to DIN 43 650, Form B
Insulation to DIN 40 050			IP 65
Supply voltage to associated amplifier	full wave rectification	V_{eff}	24 ± 10 %
	rectified 3-phase supply	V_{eff}	24 ... 35
Max. power requirement		VA	50

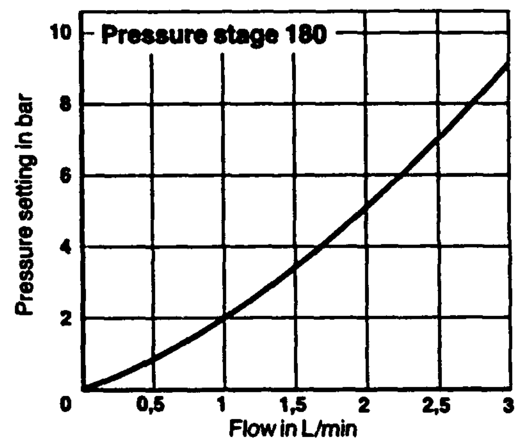
		I	II	III
Coil resistance at 20 °C (positional transducer)	Ω	56	56	112
Inductivity (positional transducer)	mH	6 ... 8		
Oscillator frequency (positional transducer)	kHz	2,5		

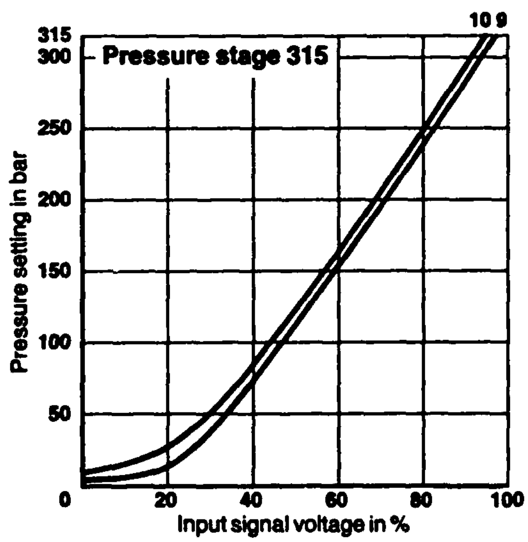
Operating Curves (measured at v = 41 mm²/sec, t = 50 °C and without back pressure at port T)

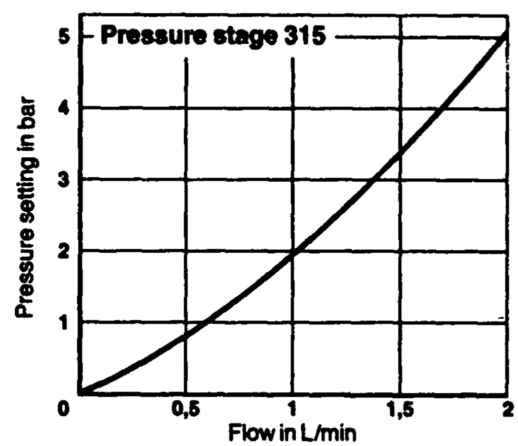








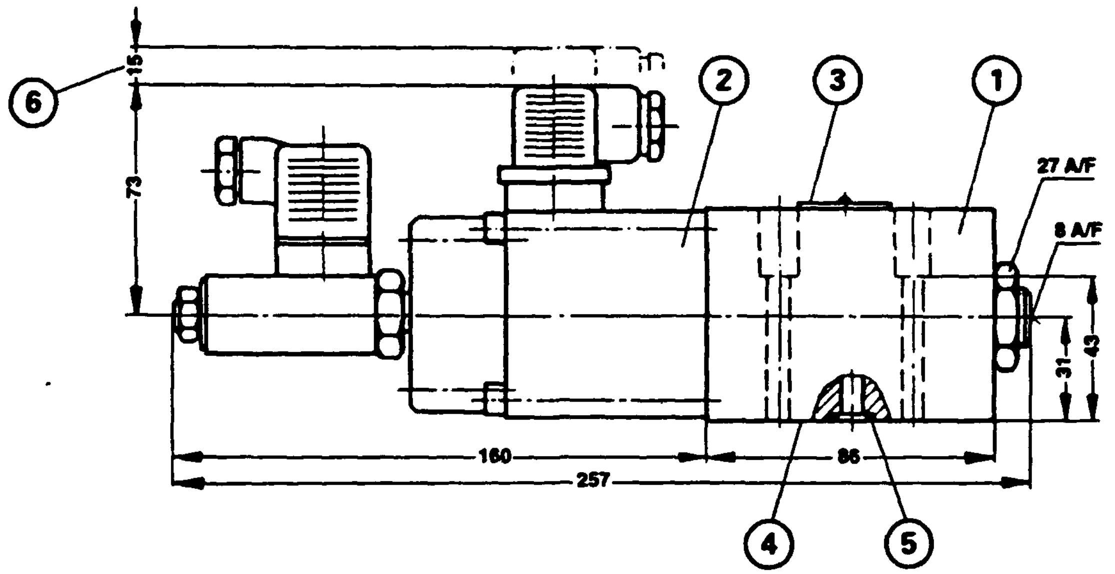


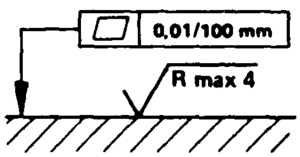


Curve 1 – with a flow of 2 L/min
Curve 2 – with a flow of 4 L/min
Curve 3 – with a flow of 6 L/min
Curve 4 – with a flow of 8 L/min
Curve 5 – with a flow of 10 L/min

Curve 6 – with a flow of 0,5 L/min
Curve 7 – with a flow of 1,5 L/min
Curve 8 – with a flow of 3 L/min
Curve 9 – with a flow of 1 L/min
Curve 10 – with a flow of 2 L/min

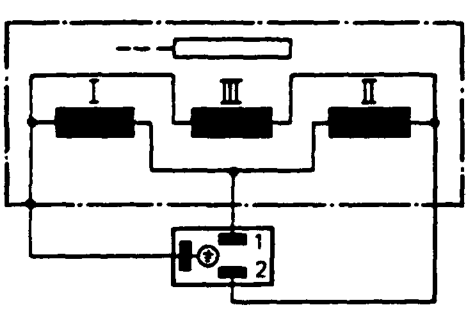
Unit dimensions: Proportional pressure relief valve (dimensions in mm)





Required surface finish of valve mounting face if a subplate is not used.

Positional Transducer



Subplates:
Type G 341/01 (1/4" BSP) and
G 342/01 (3/8" BSP)
and valve fixing screws M5 x 50 DIN 912-10.9 (tightening torque 9 Nm) must be ordered separately, to catalogue sheet RE 45052.

1 Valve body

2 Proportional solenoid with inductive positional transducer

3 Nameplate

4 Mounting face

5 O-ring 9.25 x 1.78

6 Clearance for removal of plug

Appendix 4

Unit Code (UC)

Component List

Sheet

Item	Description	Finish Size/Model №	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part №	U C	Suppl. Qty.	Stock	G I	G II	G III
1.0	Axial Piston Pump	AA4V 250 DA2.OR105A10	1.0		1									
2.0	Axial Piston Motor	AA4V 125 ELW)XX010-50	2.0		4									
3.0	Pump Control Manifold	AGA-XXXX-X-X-O	3.0		1									
3.1	Directional Valve, Pilot Operated	PBOS 10.U1X/50	3.1		1									
3.2	Pressure Relief Valve	TN 922889	3.2		1									
3.3	Proportional Pressure Relief	DBETR-1X/315	3.3		1									

Ind.	X	Date	Name	Change №	Remarks

Name

Date

Chk't

Norm

REXROTH USA

Sheet № of Sheets

Description: M113 - CENTRAL HYDRAULIC SYSTEM

Parts Code: HS-43-A53-0056-D-1

Part №

Supersedes

Superseded by

Punched and Chk'd

PU-A

Unit Code (UC): 2-Foot, 3-Foot (in), 4-Foot (sq), 5-Gal on, 6-Pounds, 7-Ton

Component List

Sheet

Item	Description	Finish Size/Model №	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part №	U C	Suppl. Qty.	Stock	I	II	III
4.0	Pilot OP Check Valve	SL52FA2-1X	4.0		1									
4.1	Directional Valve	M35SE6C2X/630G24NZr	4.1		1									
5.0	High Pressure Accumulator	(Vendor Item)	5.0		1									
	(1.0 Gal)													
6.0	Low Pressure Accumulator	(Vendor Item)	6.0		1									
	(1.0 Gal)													
7.0	Medium Pressure Accumulator	(Vendor Item)	7.0		2									
	(60 IN^3)													
8.0	Return Filter w/Bypass and	DFBN/HC240P10D1.0/BYPL24	8.0		1									
	Electric Clog Indicator													

Ind.	X	Date	Name	Change №	Remarks

Name
Date
Chk't
Norm
Sheet
№
of
Sheets

REXROTH USA

Description: M113 - CENTRAL HYDRAULIC SYSTEM

Parts Code HS-43-A53-0056-D-1

Part №

Supersedes

Superseded by

Punched and Chk'd

PU-A

CDC-D 0-81 77250

Unit Code (UC) 2-Feet 3-Feet(sq) 4-Feet(cu) 5-Gallon 6-Pounds 7-Ton

Component List

Sheet

Item	Description	Finish Size/Model №	Techn. Pos	D B	Qty. Each	KT	Item of Order	Part №	U C	Suppl. Qty.	Stock	G I	G II	G III
9.0	Heat Exchanger, Air	(Existing)	9.0		1									
10.0	Ball Type Shut-off Valve	(Vender Item)	10.0		1									
11.0	Fluid Temperature Indicator	FSA 76 1.1/FT200 M12	11.0		1									
12.0	Fluid Level Indicator	FSA 76 1.1/TM12	12.0		1									
13.0	Fluid Reservoir Assy.	(Existing)	13.0		1									

Ind.	X	Date	Name	Change №	Remarks	Name / Date / Chk't / Norm	Sheet № of Sheets	Description	Punched and Chk'd
						REXROTH USA		M113 - CENTRAL HYDRAULIC SYSTEM	PU-A
								Parts Code HS-43-A53-0056-D-1	
								Part №	
								Supersedes	Superseded by

CDG-D 6-81 77250

PRESSURE RATINGS OF STEEL PIPE

Based on ASTM A53 Grade B or A106 Grade B Seamless

ANSI B31.1, 1977 with allowances for connections and fittings reduces these working pressures approx. 25%

PIPE NOM. SIZE INCHES	PIPE SCH. NO.	PRESSURE–PSI WORKING	PRESSURE–PSI BURST	WATER HAMMER FACTOR	PIPE NOM. SIZE INCHES	PIPE SCH. NO.	PRESSURE–PSI WORKING	PRESSURE–PSI BURST	WATER HAMMER FACTOR
1/8	40	3500	20,200		2½	160	4200	15,700	5.43
1/8	80	4800	28,000		2½	XXS	6900	23,000	7.82
1/4	40	2100	19,500		3	40	1600	7,400	2.60
1/4	80	4350	26,400		3	80	2600	10,300	2.92
3/8	40	1700	16,200		3	160	4100	15,000	3.56
3/8	80	3800	22,500		3	XXS	6100	20,500	4.64
1/2	40	2300	15,600	63.4	3½	40	1500	6,800	1.94
1/2	80	4100	21,000		3½	80	2400	9,500	2.17
1/2	160	7300	26,700		4	40	1400	6,300	1.51
1/2	XXS	2300	42,100		4	80	2300	9,000	1.67
3/4	40	2000	12,900	36.1	4	160	4000	14,200	2.08
3/4	80	3500	17,600	44.5	4	XXS	5300	18,000	2.47
3/4	169	8500	25,000		5	40	1300	5,500	.960
3/4	XXS	10000	35,000		5	80	2090	8,100	1.06
1	40	2100	12,100	22.3	5	160	3850	13,500	1.32
1	80	3500	15,900	26.8	5	XXS	4780	16,200	1.49
1	160	5700	22,300	36.9	6	40	1210	5,100	.666
1	XXS	9500	32,700	68.3	6	80	2070	7,800	.738
1¼	40	1800	10,100	12.9	6	160	3760	13,000	.912
1¼	80	3000	13,900	15.0	6	XXS	4660	15,000	1.02
1¼	160	4400	18,100	18.2	8	40	1100	4,500	.385
1¼	XXS	7900	27,700	30.5	8	80	1870	6,900	.422
1½	40	1700	9,100	9.46	8	160	3700	12,600	.529
1½	80	2800	12,600	10.9	8	XXS	3560	12,200	.519
1½	160	4500	17,700	13.7	10	40	1030	4,100	.244
1½	XXS	7200	25,300	20.3	10	*80	1800	6,600	
2	40	1500	7,800	5.74	10	160	3740	12,500	.340
2	80	2500	11,000	6.52	10	XXS	3300	11,200	
2	160	4600	17,500	8.60	12	@40	1000	3,800	
2	XXS	6300	22,100	10.9	12	**80	1800	6,500	
2½	40	1900	8,500	4.02	12	160	3700	12,300	.239
2½	80	2800	11,500	4.54	12	XXS	2700	9,400	

The allowable pressures were calculated by the formula in the Code for Pressure Piping, ASA B31.1-1955, Section 3, par. 324(a),

$$P = \frac{2S(t-C)}{D-2y(t-C)}$$

where P = allowable pressure in lb per sq in. (gauge)
S = allowable working stress in lb per sq in.
D = outside diameter in inches
t = design thickness in inches, or 12½% less than the nominal thickness shown in the table
C = allowance in inches for corrosion and/or mechanical strength (C = 0.05" has been used above for all pipe sizes)
y = a coefficient having values for ferritic steels, as follows:
0.4 up to and including 900° F
0.5 for 950°F
0.7 for 1000°F and above

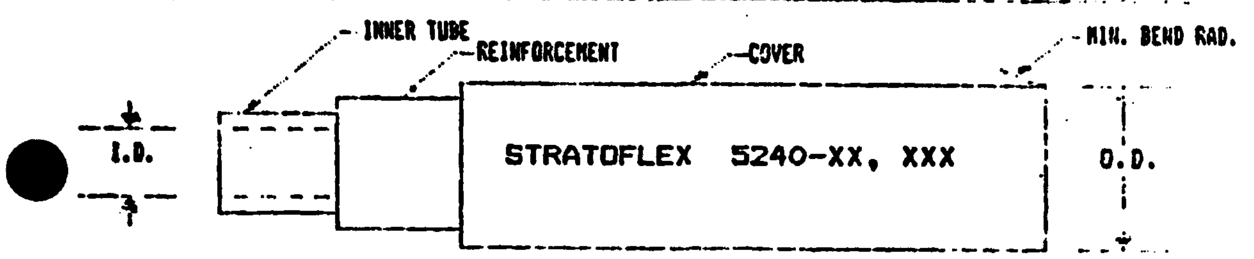
The allowable working stresses were obtained from the Code for Pressure Piping, ASA B31.1-1955, Table 12.
Hydraulic machinery piping is not covered by the Code for Pressure Piping, but it is current practice to use stresses comparable with those given for *Refinery and Oil Transportation Piping*, Div. A. The allowable working pressures at 100° F tabulated above accordingly may be used, provided that water hammer or shock conditions are considered by reducing these values by the product of the flow rate in gallons per minute and the Water Hammer Factor tabulated above.

Thus if the flow rate is 100 gpm in a 2" extra strong line, the shock pressure created by water hammer is 100 x 6.52 = 652 lbs. per sq in.; by deducting this from the value of 2500 lb per sq in. shown in the table the allowable static working pressure is found to be 1848 lb per sq in.

Burst pressures for pipe were calculated using formula $P = \frac{2St}{OD}$

Where P = internal burst pressure, psig
S = allowable stress (60,000 psi)
OD = outside diameter of tube in inches
t = nominal wall thickness

NOTES: * Not extra strong. Schedule 60 is extra strong in this size.
** Not extra strong. Extra strong does not have a schedule number in this size! (ID of 12" XS is 11.75 inches)
@ Not standard weight. Standard weight does not have a schedule number in this size! (ID of 12" Standard is 12.00 inches).



DASH SIZE	NOM ID	MAX ID	MIN ID	MAX HOSE OD	MIN HOSE OD	MAX WIRE OD	MIN WIRE OD	MAX WALL *	MIN WALL *	OPER PRESS (PSI)	BURST PRESS (PSI)	BEND RAD (IN)	WT LBS/IN
-16	1.000	1.040	0.985	1.672	1.578	1.531	1.469	.258	.229	6,000	24,000	12.00	~~.060~~ .171
-20	1.250	1.297	1.235	2.019	1.901	1.887	1.793	.307	.267	6,000	24,000	17.50	.221
-24	1.500	1.547	1.485	2.343	2.218	2.172	2.078	.324	.285	6,000	24,000	20.00	~~.600~~ .271

NOTES:

HOSE CONSTRUCTION: Seamless Neoprene compounded inner tube, optional fiber overlay, reinforced with multiple wraps of high tensile steel wire, each separated by interlays, and optional fiber overlay, and a black Neoprene compounded cover.

MARKING: Hose to be marked with Stratoflex name and part number. (See HMS 5240)

PROOF TEST: Hydrostatic pressure test at two times the recommended operating pressure.

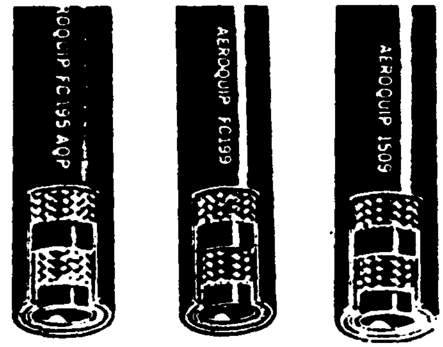
RECOMMENDED USAGE: Extra high pressure service with petroleum base fluids or water.

RECOMMENDED TEMP. LIMITS: -40 degrees F. to +250 degrees F.

* Hose wall thickness is I.D. to wire O.D. The wall thickness must be held; however, the hose cannot exceed specified I.D. and O.D. dimensions.

STRATOFLEX HOSE STANDARD

Drawn by: JRC Date: 7-23-85 Checked by: UKM 7-23-85 Approved by: [signature] Date: 7-23-85	STRATOFLEX INC. FORT WORTH TEXAS	HOSE-INDUSTRIAL RUBBER EXTRA HIGH PRESSURE Change Letter: A
Release No: 2453 Date: 7/23/85		5240



FC195 FC199 1509

2-wire braid
FC195 AQP/*HI-IMPULSE*
SAE100R2A

A Q P

Construction: AQP elastomer tube, 2-wire braid reinforcement and blue AQP cover.

Application: High pressure hydraulics, petroleum based fluids and fire resistant types. For more specific information on fluid applications, see pages 18–22.

Operating Temperature Range: Suitable for many applications between −40°F. and +300°F. (−40°C. and +150°C.) Specific high temperatures are shown with each general fluid type listed on pages 18–22.

Fittings: Pages 44–49.
Reusable, see Aeroquip Catalog 254.

For complete Agency Listings: See page 23.

Part Number	Hose I.D. (inches)	Hose O.D. (inches)	Maximum Operating Pressure (psi)	Minimum Burst Pressure (psi)	Minimum Bend Radius* (inches)	Vacuum Service (in./Hg)	Weight per ft. (lbs.)
FC195-04	.25	.69	5750	20000	4.00		.33
FC195-06	.38	.84	5000	16000	5.00		.44
FC195-08	.50	.97	4250	14000	7.00		.55
FC195-10	.62	1.09	3250	11000	8.00		.61
FC195-12	.75	1.25	3000	9000	9.50		.82
FC195-16	1.00	1.56	2500	8000	12.00		1.03
FC195-20	1.25	2.00	2250	6500	16.50		1.75
FC195-24	1.50	2.25	1750	5000	20.00		1.97
FC195-32	2.00	2.75	1500**	4500	25.00		2.50

2-wire braid
FC199 SAE100R2A

Construction: Synthetic rubber tube, 2-wire braid reinforcement and synthetic rubber cover.

Application: For high pressure hydraulics, crude, fuel and lubricating oils, gasoline. For more specific information on fluid applications, see pages 18–22.

Operating Temperature Range: −40°F. to +200°F. (−40°C. to +93°C.)

Fittings: Pages 44–49.

For complete Agency Listings: See page 23.

Part Number	Hose I.D. (inches)	Hose O.D. (inches)	Maximum Operating Pressure (psi)	Minimum Burst Pressure (psi)	Minimum Bend Radius* (inches)	Vacuum Service (in./Hg)	Weight per ft. (lbs.)
FC199-04	.25	.69	5000	20000	4.00		.33
FC199-06	.38	.84	4000	16000	5.00		.44
FC199-08	.50	.97	3500	14000	7.00		.55
FC199-10	.62	1.09	2750	11000	8.00		.61
FC199-12	.75	1.25	2250	9000	9.50		.82
FC199-16	1.00	1.56	2000	8000	12.00		1.03
FC199-20	1.25	2.00	1625	6500	16.50		.173

2-wire braid
1509 SAE100R2A

Construction: Synthetic rubber tube, 2-wire braid reinforcement and synthetic rubber cover.

Application: Hydraulic system service with petroleum and water-glycol base fluids, for general industrial service. For more specific information on fluid applications, see pages 18–22.

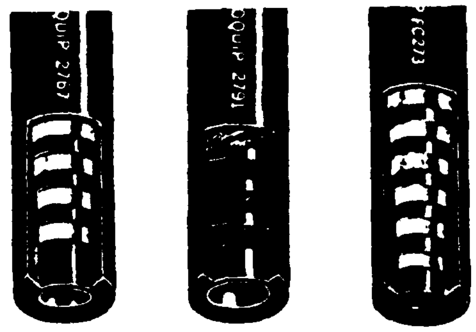
Operating Temperature Range: −40°F. to +200°F. (−40°C. to +93°C.)

Fittings: Pages 44–49.
Reusable, see Aeroquip Catalog 254.

For complete Agency Listings: See page 23.

Part Number	Hose I.D. (inches)	Hose O.D. (inches)	Maximum Operating Pressure (psi)	Minimum Burst Pressure (psi)	Minimum Bend Radius* (inches)	Vacuum Service (in./Hg)	Weight per ft. (lbs.)
1509-4	.25	.69	5000	20000	4.00		.33
1509-6	.38	.84	4000	16000	5.00		.44
1509-8	.50	.97	3500	14000	7.00		.55
1509-10	.62	1.09	2750	11000	8.00		.61
1509-12	.75	1.25	2250	9000	9.50		.82
1509-16	1.00	1.56	2000	8000	12.00		1.03
1509-20	1.25	2.00	1625	6500	16.50		1.75
1509-24	1.50	2.25	1250	5000	20.00		1.97
1509-32	2.00	2.75	1125	4500	25.00		2.50

**See page 15 for bend radius data.*
***1250 psi when used with reusable fittings.*



2767 2791 FC273

4-heavy spiral wire
2767

Part Number	Hose I.D. (inches)	Hose O.D. (inches)	Maximum Operating Pressure (psi)	Minimum Burst Pressure (psi)	Minimum Bend Radius* (inches)	Vacuum Service (in./Hg)	Weight per ft. (lbs.)
2767-20	1.25	2.00	3000	12000	18.00		2.13
2767-24	1.50	2.25	2500	10000	22.00		2.31
2767-32	2.00	2.75	2250	8000	28.00		2.92

Construction: Synthetic EPDM rubber tube, 4-heavy spiral wire reinforcement, synthetic rubber cover. Green for identification.

Application: For high pressure hydraulic systems using phosphate ester base hydraulic fluids. For more specific information on fluid applications, see pages 18–22.

Operating Temperature Range: −40°F. to +200°F. (−40°C. to +93°C.)

Fittings: Pages 58–60.
Reusable, see Aeroquip Catalog 254.

For complete Agency Listings: See page 23.

4-heavy spiral wire
2791 SAE100R10A

Part Number	Hose I.D. (inches)	Hose O.D. (inches)	Maximum Operating Pressure (psi)	Minimum Burst Pressure (psi)	Minimum Bend Radius* (inches)	Vacuum Service (in./Hg)	Weight per ft. (lbs.)
2791-32	2.00	2.78	2500	10000	28.00		3.76

Construction: Synthetic rubber tube, 4-heavy spiral wire reinforcement, synthetic rubber cover.

Application: High pressure hydraulics. For more specific information on fluid applications, see pages 18–22.

Operating Temperature Range: −40°F. to +200°F. (−40°C. to +93°C.)

Fittings: Pages 58–60.
Reusable, see Aeroquip Catalog 254.

For complete Agency Listings: See page 23.

4 or 6-spiral wire
FC273

Part Number	Hose I.D. (inches)	Hose O.D. (inches)	Maximum Operating Pressure (psi)	Minimum Burst Pressure (psi)	Minimum Bend Radius* (inches)	Vacuum Service (in./Hg)	Weight per ft. (lbs.)
FC273-12	.75	1.28	5000	20000	9.50		1.08
FC273-16	1.00	1.54	5000	20000	12.00		1.41
FC273-20	1.25	1.98	5000	20000	16.50		2.53
FC273-24	1.50	2.28	5000	20000	20.00		3.35
FC273-32	2.00	2.80	5000	20000	25.00		5.00

Construction: Synthetic rubber tube; multiple heavy spiral wire (4 plies for -12, -16; 6 plies for -20, -24 and -32); brown synthetic rubber cover.

Application: High pressure hydraulics. For more specific information on fluid applications, see pages 18–22.

Operating Temperature Range: −40°F. to +250°F. (−40°C. to 121°C.)

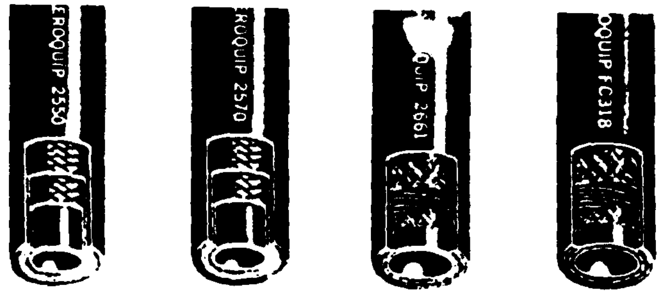
Fittings: Pages 74–77.

For complete Agency Listings: See page 23.

*See page 15 for bend radius data.

Aeroquip

Special application hose



2550 2570 2661 FC318

Air brake
2550/2554†

Construction: Synthetic rubber tube, two textile braids and synthetic rubber cover.
Application: Tractor to trailer air brake lines, axle chamber lines and tractor service lines.
Operating Temperature Range: −40°F. to +250°F. (−40°C. to +121°C.) 2554, −65°F. (−54°C.)†
Fittings: Contact Aeroquip.
Reusable, see Aeroquip Catalog 254.
For complete Agency Listings: See page 23.

Part Number	Hose I.D. (inches)	Hose O.D. (inches)	Maximum Operating Pressure (psi)	Minimum Burst Pressure (psi)	Minimum Bend Radius* (inches)	Vacuum Service (in./Hg)	Weight per ft. (lbs.)
2550-6	.38	.75	225	900	1.75		.20
2554-6†	.38	.75	225	900	3.75		.20

Air brake
2570

Construction: Synthetic rubber tube, two textile braids and synthetic rubber cover.
Application: Tractor to trailer air brake lines, axle chamber lines and tractor service lines.
Operating Temperature Range: −40°F. to +250°F. (−40°C. to +121°C.)
Fittings: Contact Aeroquip.
Reusable, see Aeroquip Catalog 254.
For complete Agency Listings: See page 23.

Part Number	Hose I.D. (inches)	Hose O.D. (inches)	Maximum Operating Pressure (psi)	Minimum Burst Pressure (psi)	Minimum Bend Radius* (inches)	Vacuum Service (in./Hg)	Weight per ft. (lbs.)
2570-4	.25	.62	225	900	1.50		.16
2570-6	.38	.75	225	900	1.75		.23
2570-8	.50	.88	225	900	2.00		.28
2570-10	.62	1.06	225	900	2.25		.34

Wire inserted suction hose
2661 SAE100R4

A Q P

Construction: AQP elastomer tube, reinforcement consisting of a helical wire between an inner and outer textile braid and blue AQP elastomer cover.
Application: Suction and transfer applications for hydraulics, fuel and lubricating oils, gasoline, and water and many other industrial fluids. For chemical transfer applications, see Aeroquip Bulletin 5509.
Operating Temperature Range: −40°F. +300°F. (−40°C. to +150°C.)
Fittings: Pages 49–53, 57–59.
Reusable, see Aeroquip Catalog 254.
For complete Agency Listings: See page 23.

Part Number	Hose I.D. (inches)	Hose O.D. (inches)	Maximum Operating Pressure (psi)	Minimum Burst Pressure (psi)	Minimum Bend Radius* (inches)	Vacuum Service (in./Hg)	Weight per ft. (lbs.)
2661-12	.75	1.25	300††	1200	5.00	28	.42
2661-16	1.00	1.50	250††	1000	6.00	28	.50
2661-20	1.25	1.80	200††	800	8.00	28	.90
2661-24	1.50	2.08	150††	600	10.00	28	1.13
2661-32	2.00	2.50	100††	400	12.00	28	1.30
2661-40	2.50	3.12	100	400	14.00	28	1.72
2661-48	3.00	3.62	100	400	18.00	28	1.96
2661-64	4.00	4.69	50	200	25.00	28	3.0[illegible]

Suction hose
FC318 SAE100R4

Construction: Synthetic rubber tube, reinforcement consisting of a helical wire between an inner and outer textile braid and synthetic rubber cover.
Application: Suction and transfer applications for hydraulics, fuel and lubricating oils, gasoline, and water. For more specific information on fluid applications, see pages 18–22.
Operating Temperature Range: −40°F. to +200°F. (−40°C. to +93°C.)
Fittings: Pages 49–53, 57–59.
Reusable, see Aeroquip Catalog 254.
For complete Agency Listings: See page 23.

Part Number	Hose I.D. (inches)	Hose O.D. (inches)	Maximum Operating Pressure (psi)	Minimum Burst Pressure (psi)	Minimum Bend Radius* (inches)	Vacuum Service (in./Hg)	Weight per ft. (lbs.)
FC318-12	.75	1.25	300†	1200	5.00	28	.4[illegible]
FC318-16	1.00	1.50	250†	1000	6.00	28	.5[illegible]
FC318-20	1.25	1.80	200†	800	8.00	28	.9[illegible]
FC318-24	1.50	2.08	150†	600	10.00	28	1.1[illegible]
FC318-32	2.00	2.50	100†	400	12.00	28	1.3[illegible]
FC318-40	2.50	3.12	100	400	14.00	28	1.7[illegible]
FC318-48	3.00	3.62	100	400	18.00	28	1.9[illegible]

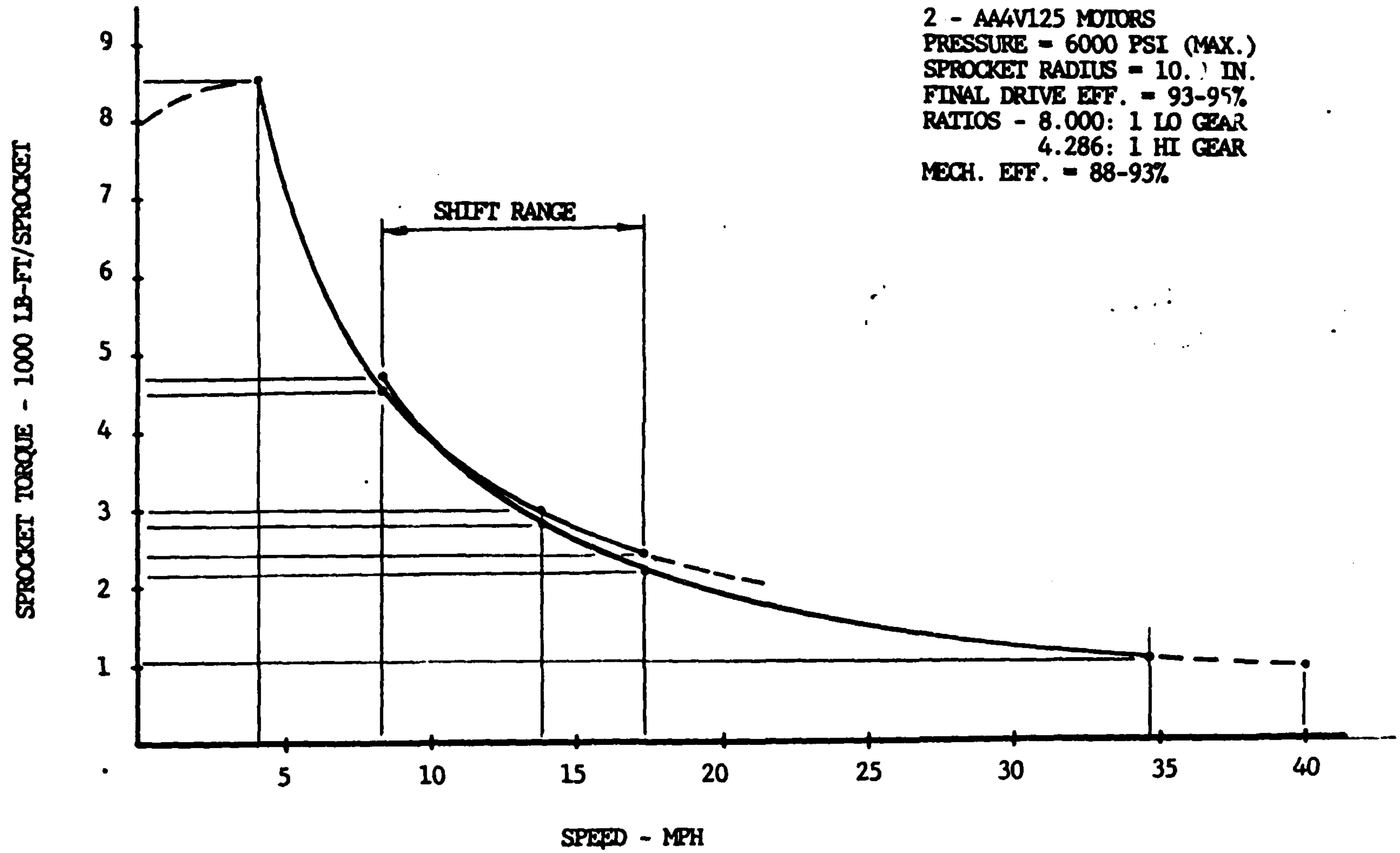
**See page 15 for bend radius data.*
†Low temperature (−65°F. or −54°C.) 2554 Hose conforms to Ordnance Spec. MIL-H-3992B, Type 1, Class
††Maximum working pressure for band clamp fittings is 50 psi.

Appendix 5

M

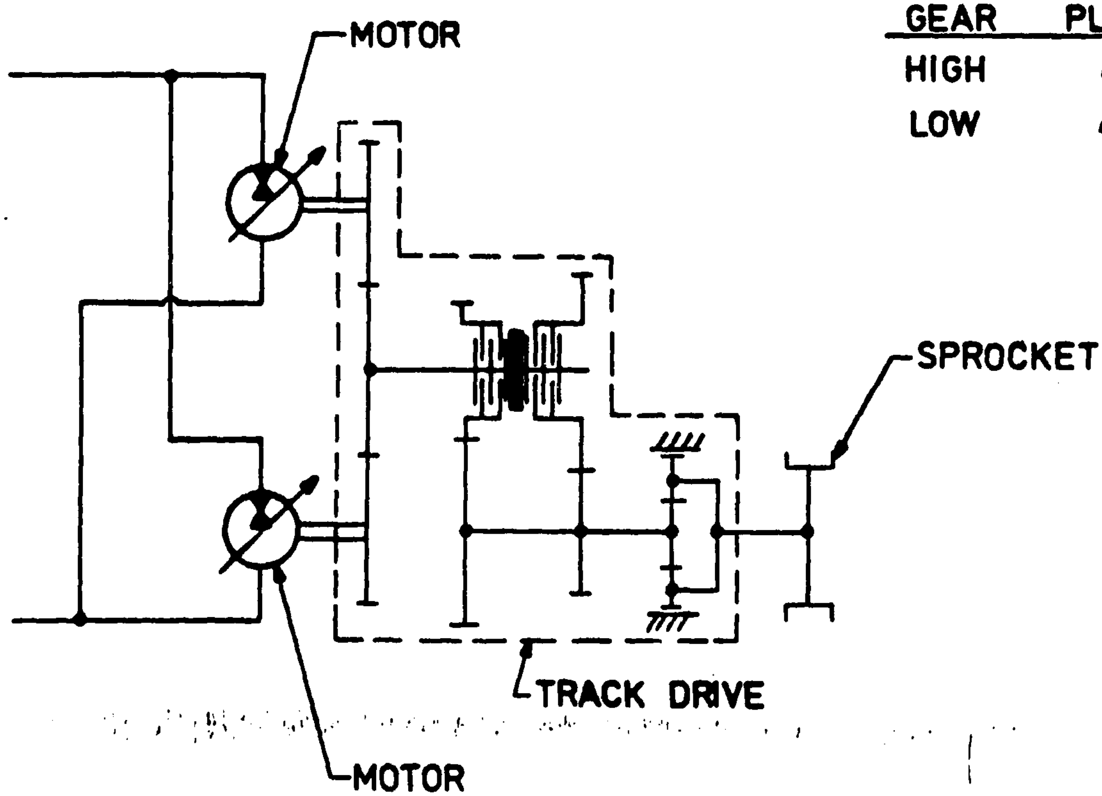
HDSR

TORQUE - SPEED CURVE

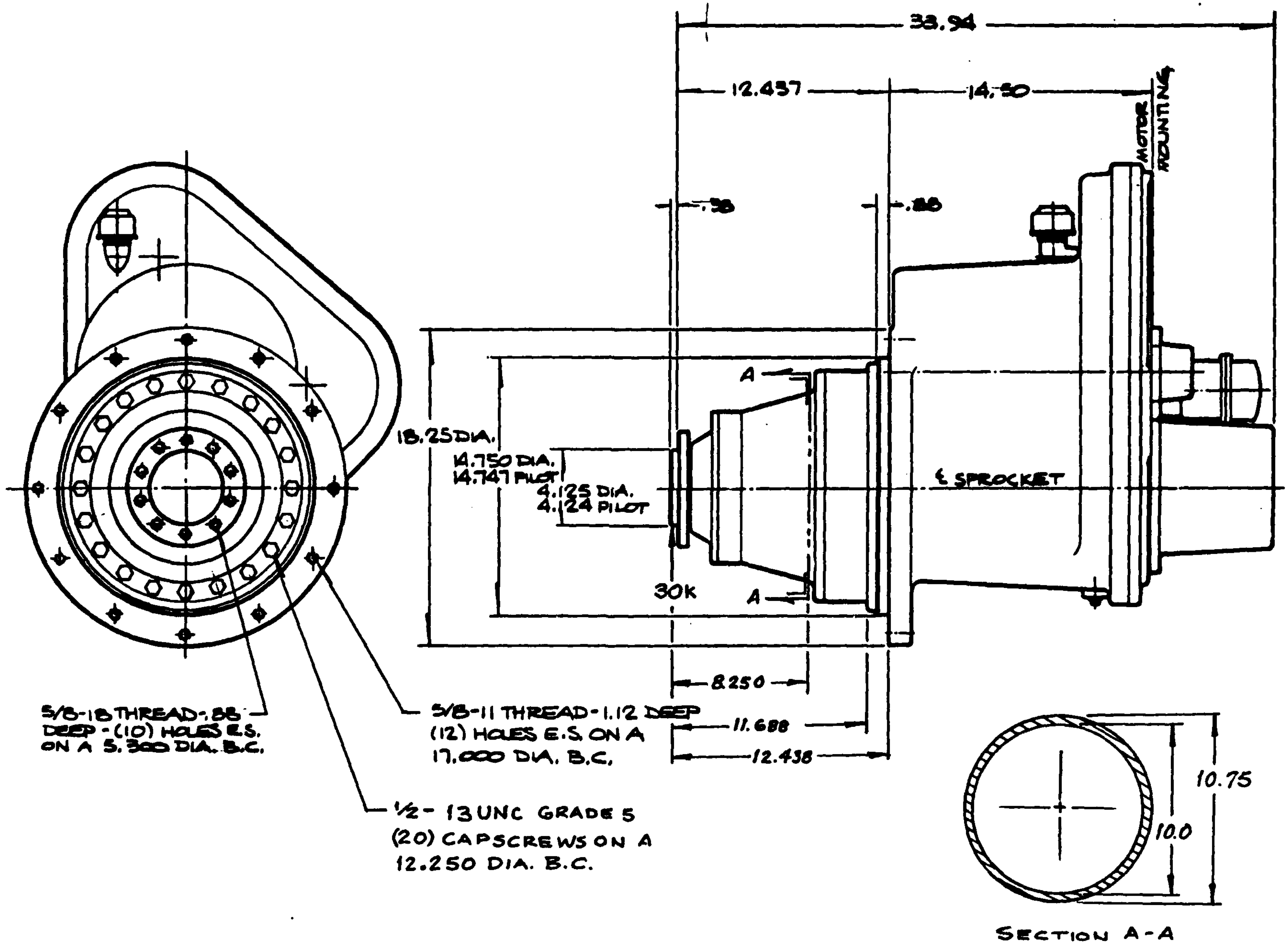


-M113-
TRACK DRIVE SCHEME

RATIOS			
GEAR	PLANET.	SPUR	TOTAL
HIGH	4:1	1.07:1	4.28:1
LOW	4:1	2.0:1	8.0:1



Appendix 6



33.94
12.437
14.50
MOTOR MOUNTING
.38
.88
18.25 DIA.
14.750 DIA.
14.747 PILOT
4.125 DIA.
4.124 PILOT
℄ SPROCKET
A
A
30K
8.250
11.688
12.438
5/8-18 THREAD-.88 DEEP-(10) HOLES E.S. ON A 5.300 DIA. B.C.
5/8-11 THREAD-1.12 DEEP (12) HOLES E.S. ON A 17.000 DIA. B.C.
1/2-13 UNC GRADE 5 (20) CAPSCREWS ON A 12.250 DIA. B.C.
10.75
10.0
SECTION A-A

Final Drive and fastener stresses due to a 30,000 lb load applied at the sprocket $\mathcal{L}$.

Output Housing Stress (Bending)

Section A-A

$$I = \frac{\pi}{64}(D_o^4 - D_i^4) = \frac{\pi}{64}(3355) = 164 \text{ IN}^4$$

$$\sigma_B = \frac{Mc}{I} = \frac{30{,}000(8.25)(5.375)}{164} = 8{,}111 \text{ Lb/in}^2 < 37{,}000 \text{ psi}$$

Output Housing / Ring Gear Bolt Stress (Tension)

$$\text{Bolt Force (Max.)} = \frac{M L_n}{(NL_1^2 + NL_2^2 --- + NL_n^2)}$$

Where: L = distance from tipping point
N = No. of bolts / row
M = Tipping Moment

$$\text{Bolt Force} = \frac{30{,}000(11.6875)(12.25)}{2(.09 + 1.368 + 6.374 + 19.912 + 35.515 + 64.284 + 95.579 + 122.77 + 142.83) + 160.0}$$

$$= 3810 \text{ Lb}_f$$

$$\text{Bolt Stress} = P/A = \frac{3810}{.125} = 30{,}500 \text{ Lb/in}^2 < 80{,}000 \text{ psi}$$

(SAE Grade 5)

Mounting Bolt Stress (Tension)

$$\text{Bolt Force} = \frac{30{,}000(12.438)(17)}{2(1.29 + 18.06 + 72.25 + 162.56 + 251.58) + 289}$$

$$= 4855 \text{ Lb}_f$$

$$\text{Bolt Stress} = \frac{4855}{.24} = 20{,}230 \text{ Lb/in}^2 < 80{,}000 \text{ psi}$$

(SAE Grade 5)

R. Cushman & Associates, Inc.
32367 W. 8 Mile Road
Livonia, Michigan 48152
(313) 477-5599

THE REXROTH CORPORATION
Industrial Hydraulics Division
2315 City Line Road
Bethlehem, Pa. 18017

Sept. 6, 1986

Attn: Mr. Robert M. Dick; Manager, Military Vehicle Systems.

Subj: Engineering calculations for drawing 10007, Two Speed Final Drive.

Dear Bob:

You will find the gear and bearing calculations attached. If you have any questions, please do not hesitate to call.

Please note that the bearing lives listed are maximum conditions, and are very conservative, so weighed life averages will be much higher.

Sincerely

Gary Hamilton
Chief Engineer

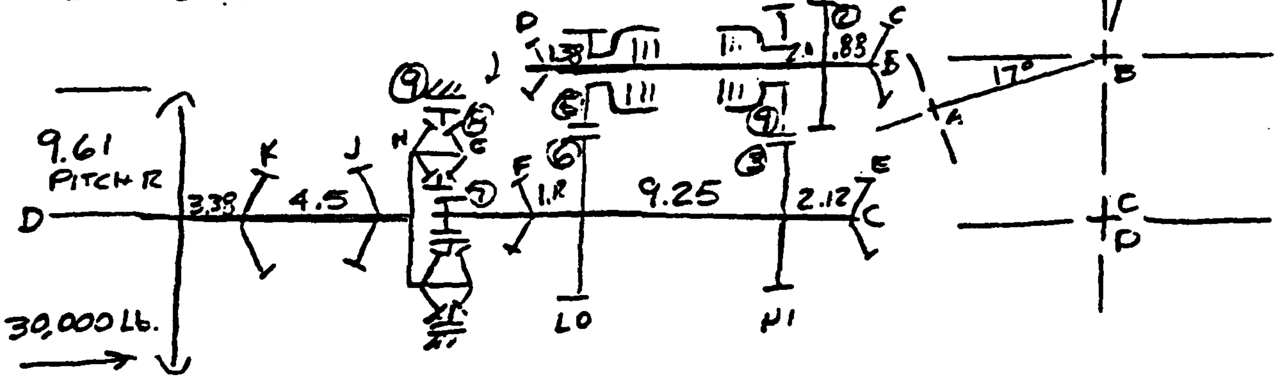
cc; Mr. Richard Cushman

H	M 113 TRACK DR CALCULATIONS	4.256:1 HI, 8.000:1 LO	?/86

MAXIMUM INPUT TORQ.
(2) HYD MOTOR 7890 LB·IN.

MAXIMUM INPUT SPEED
3250 RPM

MAXIMUM OUTPUT TORQUE
8400 LB-FT.



GEAR					MAX TORQ	SB	SS
1 (2)	35T	5DP	20°PA	1.0 FW	7878	29873	125107
2	35T	5DP	20°PA	1.0 FW	7878	29873	125107
3	30T	5DP	20°PA	1.25 FW			
4	35T	5DP	20°PA	1.25 FW			
5	25T	5DP	20°PA	1.50 FW			
6	40T	5DP	20°PA	1.50 FW			
7	16T	6DP	20°PA	2.00 FW			
8 (4)	24T	6DP	20°PA	2.00 FW			
9	64T	6DP	20°PA	2.00 FW (INTERNAL)			

BRG	BRR	K	HI CW	CCW	RPM	LO CW	CCW	RPM	MIN B-10
A 3212	3050		1199	1199	540	957	957	675	25×10⁷
B 3212	3050		1199	1199	540	957	957	675	25×10⁷
C 3767/3720	5930	1.73	4485	6880	540	1759	2072	675	73961
D 3767/3720	5930	1.73	1037	1160	540	3451	3556	675	12220
E 49585/49520	6950	1.46	3976	3976	630	481	481	422	11,943
F 49585/49520	6450	1.96	813	813	630	4881	4881	422	9009
G 3659/3620	4300	2.07	2536	2536	336	3780	3780	224	10245
H 2659/3620	4300	2.07	2536	2536	336	3780	3780	224	10245
J 582/567	10100	1.45	5286	5286	126	7878	7878	84	40,879
K 6460/6420	16800	1.61	12324	12324	126	18367	18367	84	13,265

MAX OUTPUT BRG LOAD WITH 30,000 LB SIDE FORCE
AND FULL TORQUE BOTH ADDING IN SAME DIRECTION

J = 71,945 @ 84 RPM = 25.7 HR   7.1 × RATING. BELOW 8:1
K = 82,434 @ 84 RPM = 84 HR   MAX OVERLOAD IS
ACCEPTABLE

SPUR GEAR STRESS ANALYSIS -- AGMA 221.02

PREPARED FOR REXROTH BY GARY HAMILTON

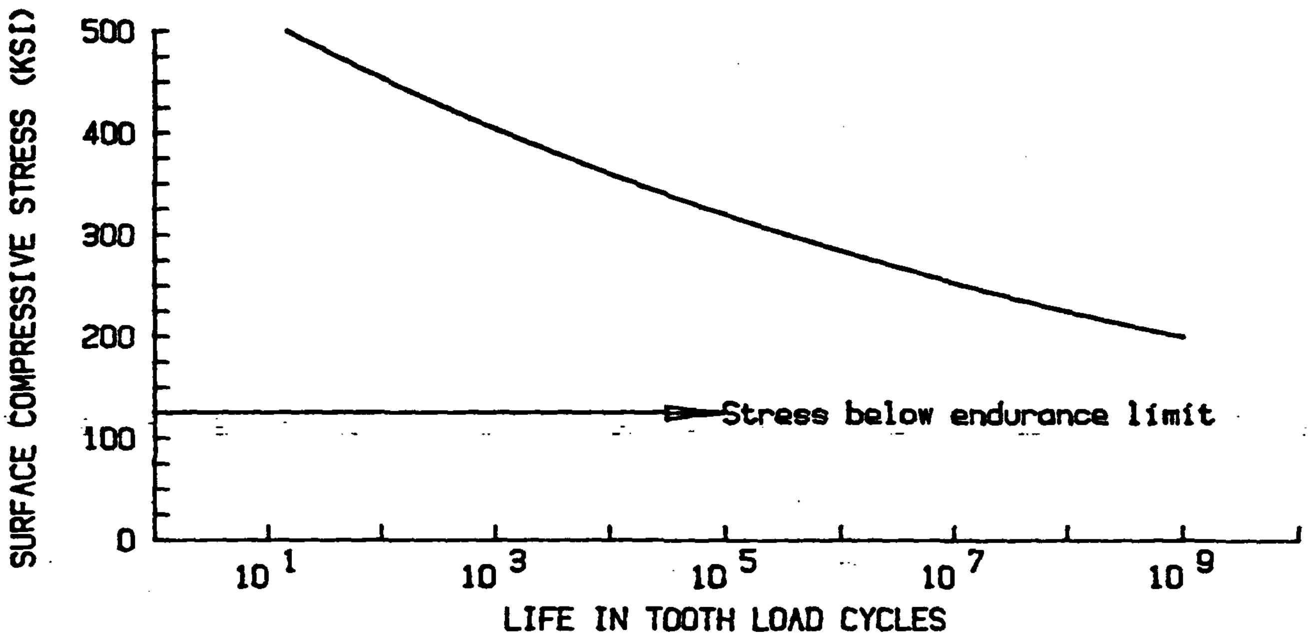
JOB NUMBER 10007

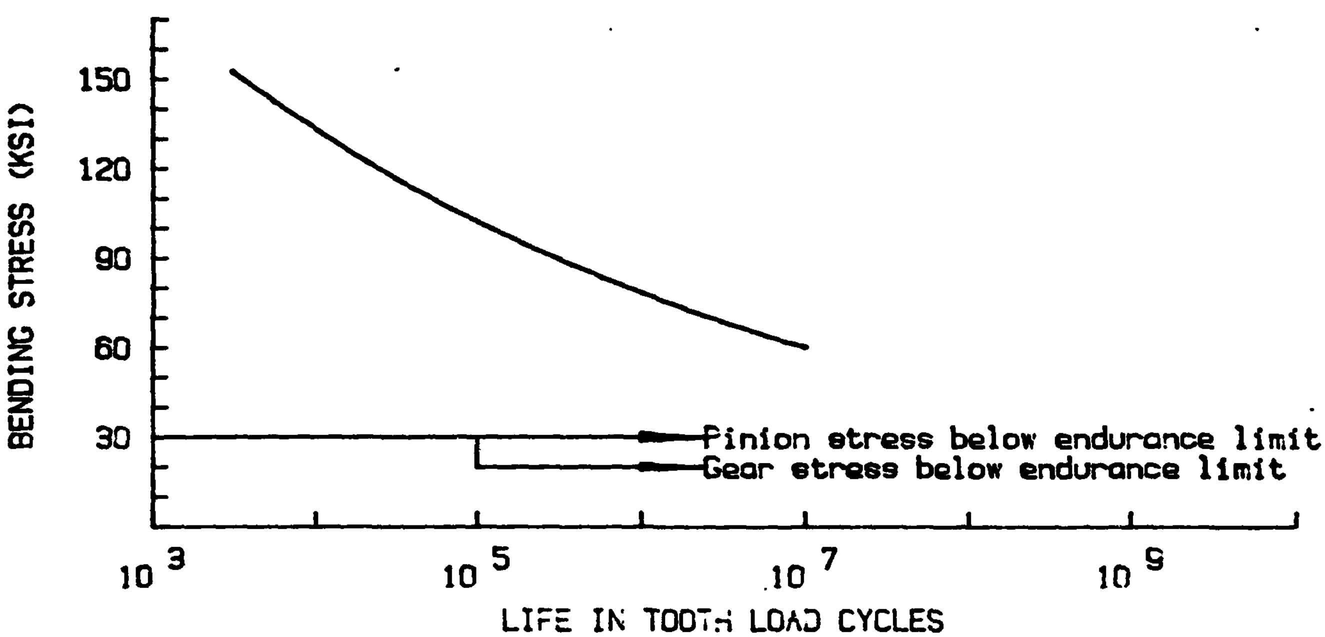
	PINION		GEAR
PART NUMBER	1		2
NUMBER OF TEETH	35		35
DIAM. PITCH		5.0000	
PRESSURE ANGLE		20.0000	
HELIX ANGLE		0.0000	
CENTER DISTANCE		7.0000	
FACE WIDTH	1.0000		1.0000
ADDENDUM	.2000		.2000
WHOLE DEPTH	.4700		.4700
HOB EDGE RADIUS	.0840		.0840
CIRC. TOOTH THICKNESS	.3100		.3100
CRITICAL THICKNESS	.3952		.3952
J FACTOR	.4463		.4463
I FACTOR		.1287	
OVERLOAD FACTOR		1.0000	
MOUNTING FACTOR		1.0000	
PITCH LINE VELOCITY		989.6017	
DYNAMIC FACTOR		.8442	
RATING STRESS			
BENDING (PSI)		60,000	
SURFACE (PSI)		200,000	
TORQUE RATING			
BENDING (LB-IN)	15,823		15,823
SURFACE (LB-IN)	20,133		20,133
POWER RATING AT 540 RPM OF PINION			
BENDING (HP)	135.5755		135.5755
SURFACE (HP)	172.5055		172.5055
STRESS AT 7878 LB-IN PINION TORQUE			
BENDING (PSI)	29,873		29,873
SURFACE (PSI)	125,107		125,107

S-N LIFE CURVES

PREPARED FOR REXROTH BY GARY HAMILTON

	PINION	GEAR
JOB NUMBER 10007		
PART NUMBER	1	2
NUMBER OF TEETH	35	35
DIAMETRAL	5.000	
INPUT TORQUE	7.878	





SPUR GEAR STRESS ANALYSIS -- AGMA 221.02

PREPARED FOR REXROTH BY GARY HAMILTON

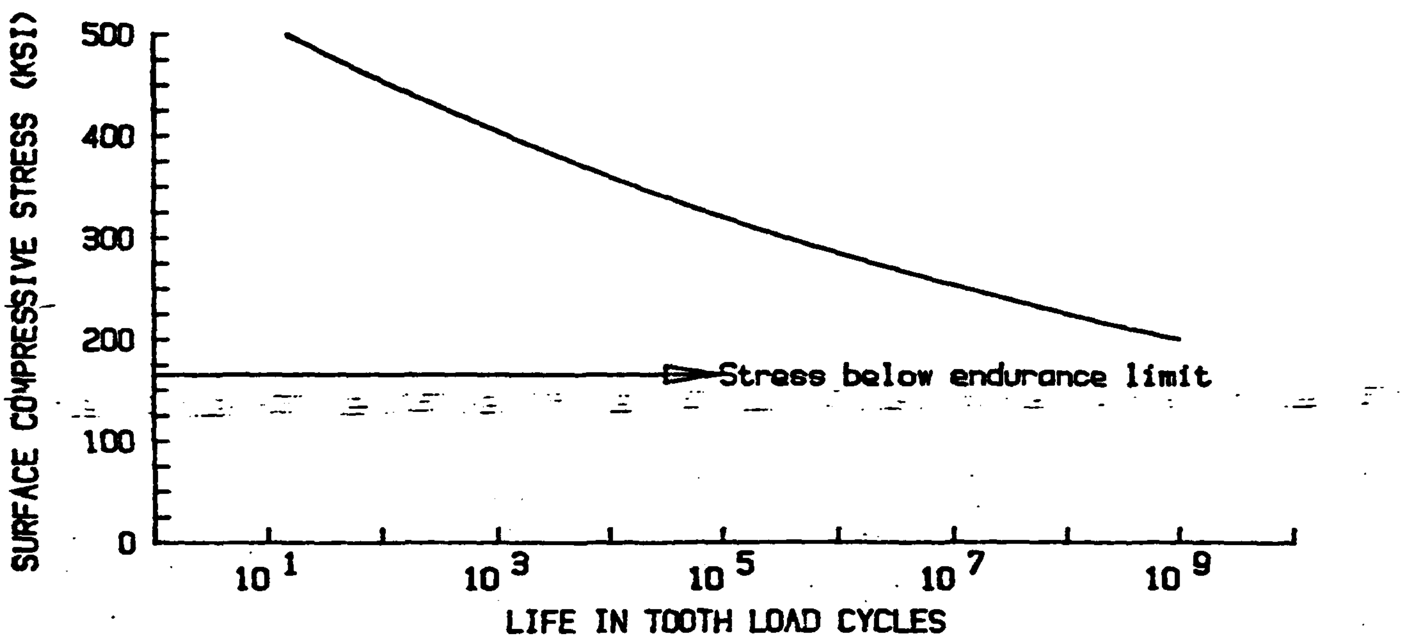
JOB NUMBER 10007

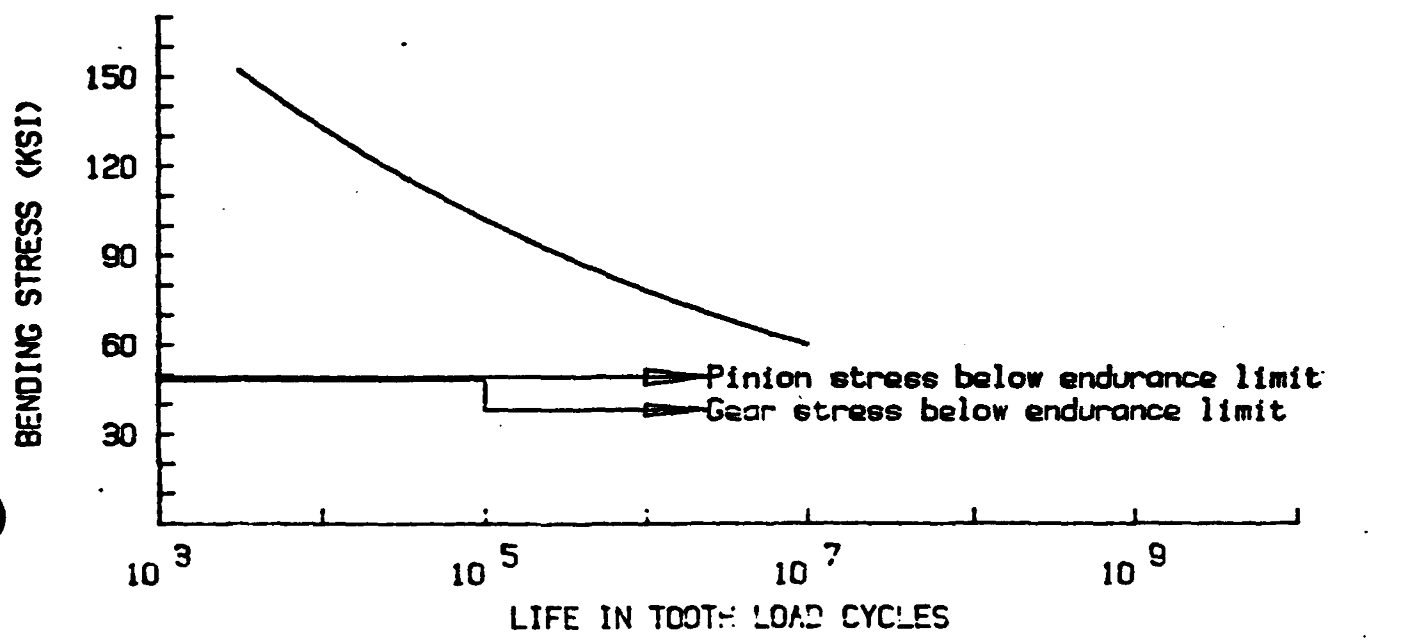
		PINION		GEAR
PART NUMBER	3		4	
NUMBER OF TEETH		30		35
DIAM. PITCH			5.0000	
PRESSURE ANGLE			20.0000	
HELIX ANGLE			0.0000	
CENTER DISTANCE			6.5000	
FACE WIDTH		1.2500		1.2500
ADDENDUM		.2000		.2000
WHOLE DEPTH		.4700		.4700
HOB EDGE RADIUS		.0840		.0840
CIRC. TOOTH THICKNESS		.3100		.3100
CRITICAL THICKNESS		.3864		.3952
J FACTOR		.4327		.4419
I FACTOR			.1373	
OVERLOAD FACTOR			1.0000	
MOUNTING FACTOR			1.0000	
PITCH LINE VELOCITY			989.6017	
DYNAMIC FACTOR			.8442	
RATING STRESS				
BENDING (PSI)			60,000	
SURFACE (PSI)			200,000	
TORQUE RATING				
BENDING (LB-IN)		16,436		19,585
SURFACE (LB-IN)		19,717		23,003
POWER RATING AT 630 RPM OF PINION				
BENDING (HP)		164.2974		167.8056
SURFACE (HP)		197.0907		197.0907
STRESS AT 13505 LB-IN PINION TORQUE				
BENDING (PSI)		49,301		48,270
SURFACE (PSI)		165,525		165,525

S-N LIFE CURVES

PREPARED FOR REXROTH BY GARY HAMILTON

JOB NUMBER 10007	PINION	GEAR
PART NUMBER	3	4
NUMBER OF TEETH	30	35
DIAMETRAL	5.000	
INPUT TORQUE	13.505	





SPUR GEAR STRESS ANALYSIS -- AGMA 221.02

PREPARED FOR REXROTH BY GARY HAMILTON

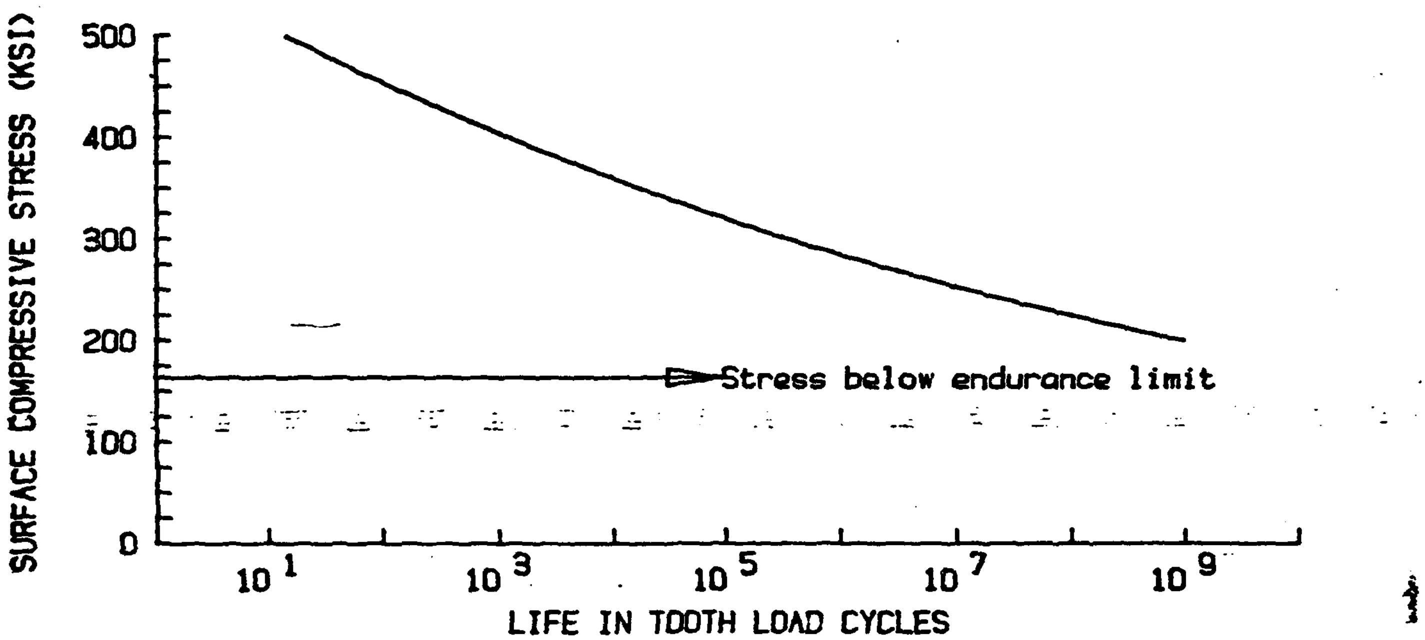
JOB NUMBER 10007

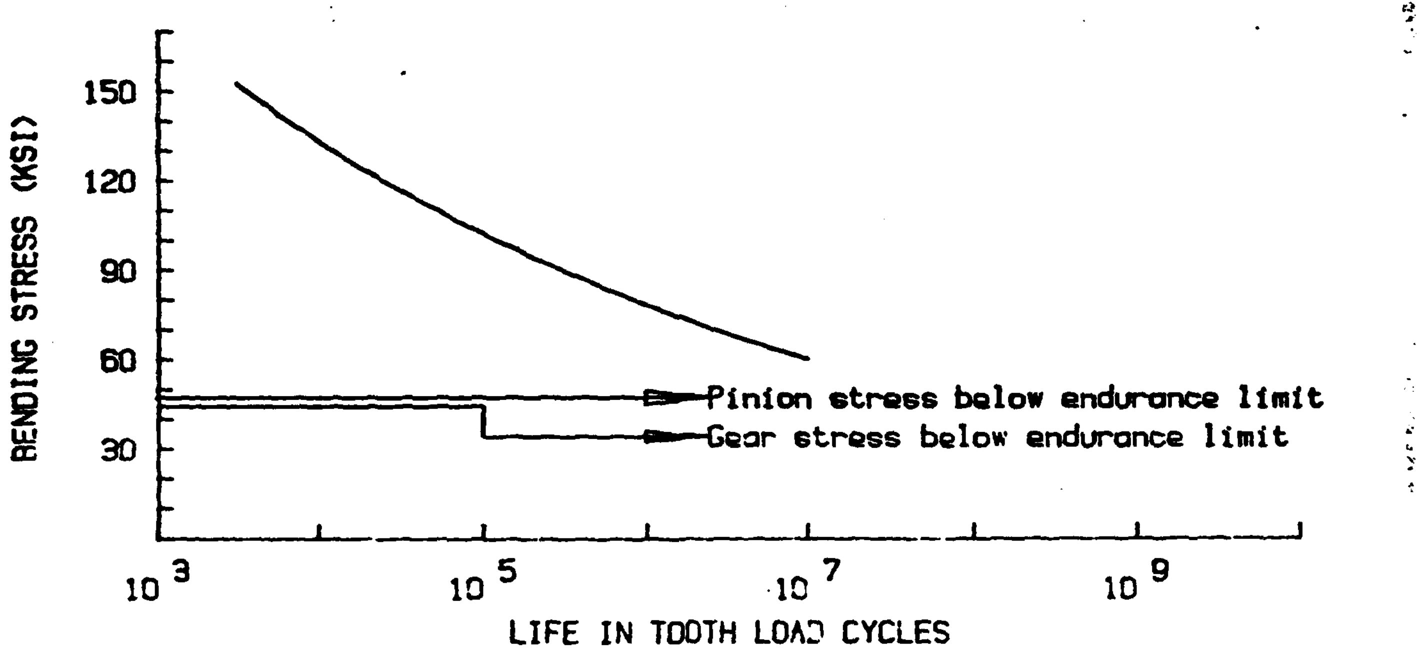
	PINION		GEAR
PART NUMBER	5		6
NUMBER OF TEETH	25		40
DIAM. PITCH		5.0000	
PRESSURE ANGLE		20.0000	
HELIX ANGLE		0.0000	
CENTER DISTANCE		6.5000	
FACE WIDTH	1.5000		1.5000
ADDENDUM	.2000		.2000
WHOLE DEPTH	.4700		.4700
HOB EDGE RADIUS	.0840		.0840
CIRC. TOOTH THICKNESS	.3100		.3100
CRITICAL THICKNESS	.3745		.4021
J FACTOR	.4179		.4469
I FACTOR		.1562	
OVERLOAD FACTOR		1.0000	
MOUNTING FACTOR		1.0000	
PITCH LINE VELOCITY		883.5729	
DYNAMIC FACTOR		.8509	
RATING STRESS			
BENDING (PSI)		60,000	
SURFACE (PSI)		200,000	
TORQUE RATING			
BENDING (LB-IN)	16,004		27,378
SURFACE (LB-IN)	18,843		30,149
POWER RATING AT 675 RPM OF PINION			
BENDING (HP)	171.4048		183.2671
SURFACE (HP)	201.8162		201.8162
STRESS AT 12605 LB-IN PINION TORQUE			
BENDING (PSI)	47,257		44,198
SURFACE (PSI)	163,576		163,576

S-N LIFE CURVES

PREPARED FOR REXROTH BY GARY HAMILTON

JOB NUMBER 10007	PINION	GEAR
PART NUMBER	5	6
NUMBER OF TEETH	25	40
DIAMETRAL	5.000	
INPUT TORQUE	12.605	





SPUR GEAR STRESS ANALYSIS -- AGMA 221.02

PREPARED FOR REXROTH BY GARY HAMILTON

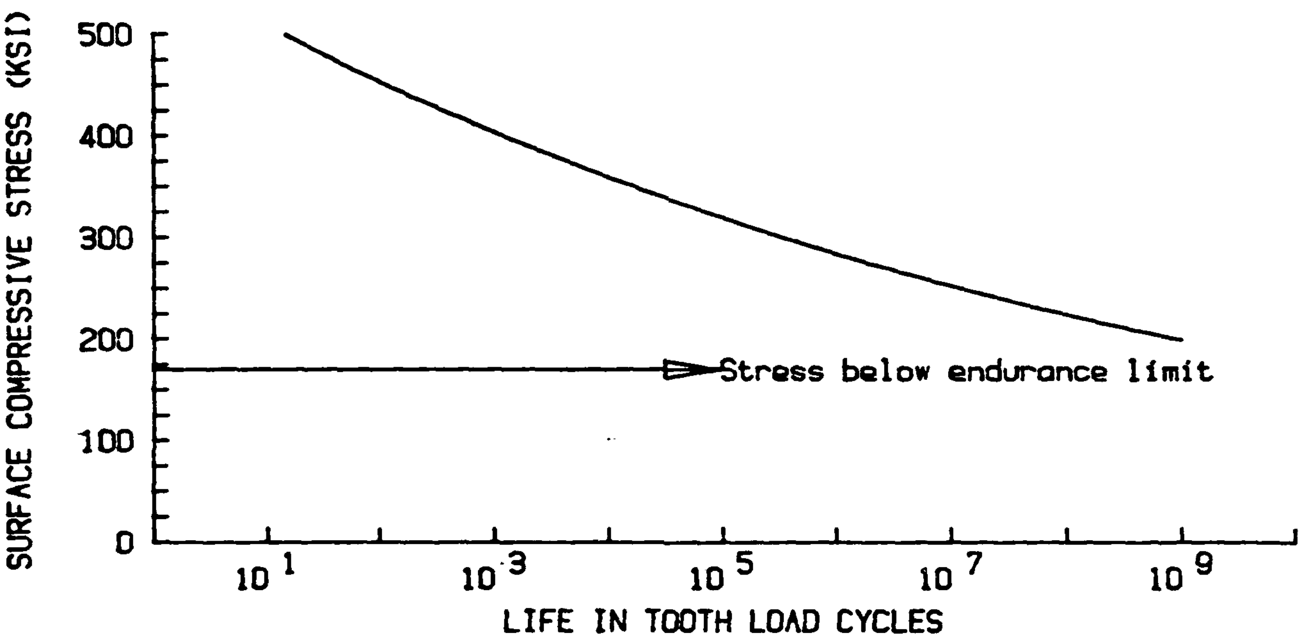
JOB NUMBER 10007

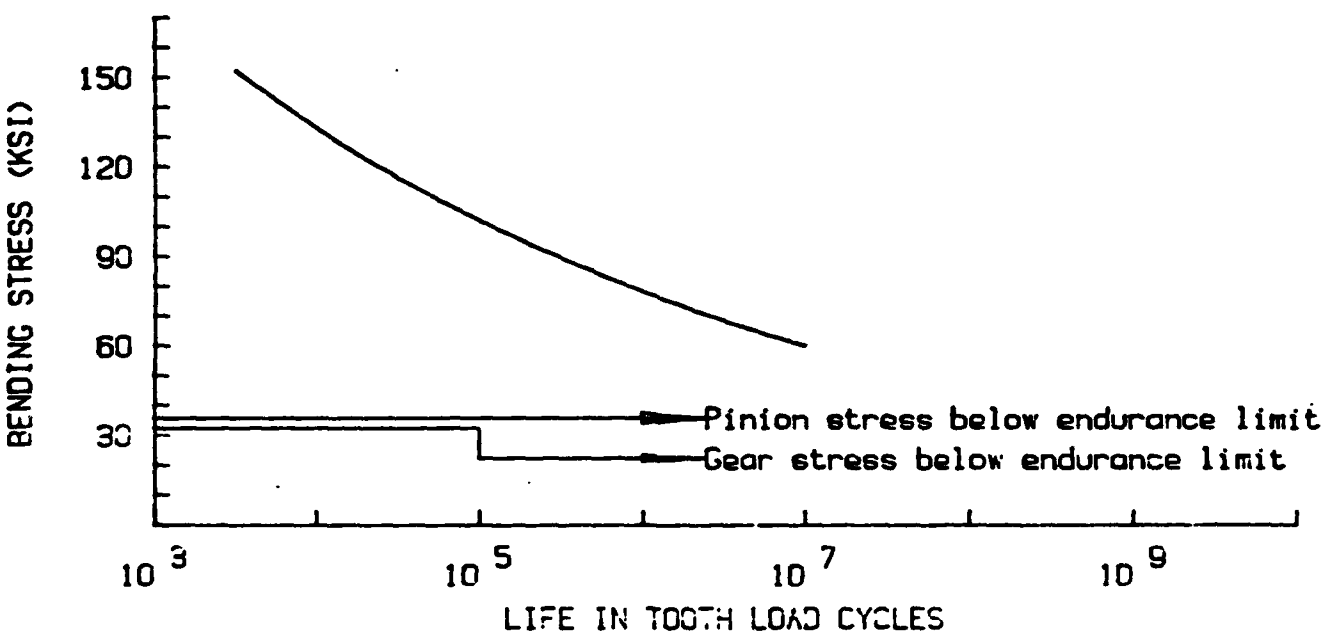
	PINION		GEAR
PART NUMBER	7		8
NUMBER OF TEETH	16		24
DIAM. PITCH		6.0000	
PRESSURE ANGLE		20.0000	
HELIX ANGLE		0.0000	
CENTER DISTANCE		3.3333	
FACE WIDTH	2.0000		2.0000
ADDENDUM	.1667		.1667
WHOLE DEPTH	.3917		.3917
HOB EDGE RADIUS	.0700		.0700
CIRC. TOOTH THICKNESS	.2580		.2580
CRITICAL THICKNESS	.2811		.3094
J FACTOR	.3494		.3862
I FACTOR		.1420	
OVERLOAD FACTOR		1.0000	
MOUNTING FACTOR		1.0000	
PITCH LINE VELOCITY		294.6116	
DYNAMIC FACTOR		.9053	
RATING STRESS			
BENDING (PSI)		60,000	
SURFACE (PSI)		200,000	
TORQUE RATING			
BENDING (LB-IN)	8,434		13,984
SURFACE (LB-IN)	6,914		10,371
POWER RATING AT 422 RPM OF PINION			
BENDING (HP)	56.4762		62.4238
SURFACE (HP)	46.2951		46.2951
STRESS AT 5040 LB-IN PINION TORQUE			
BENDING (PSI)	35,856		32,440
SURFACE (PSI)	170,765		170,765

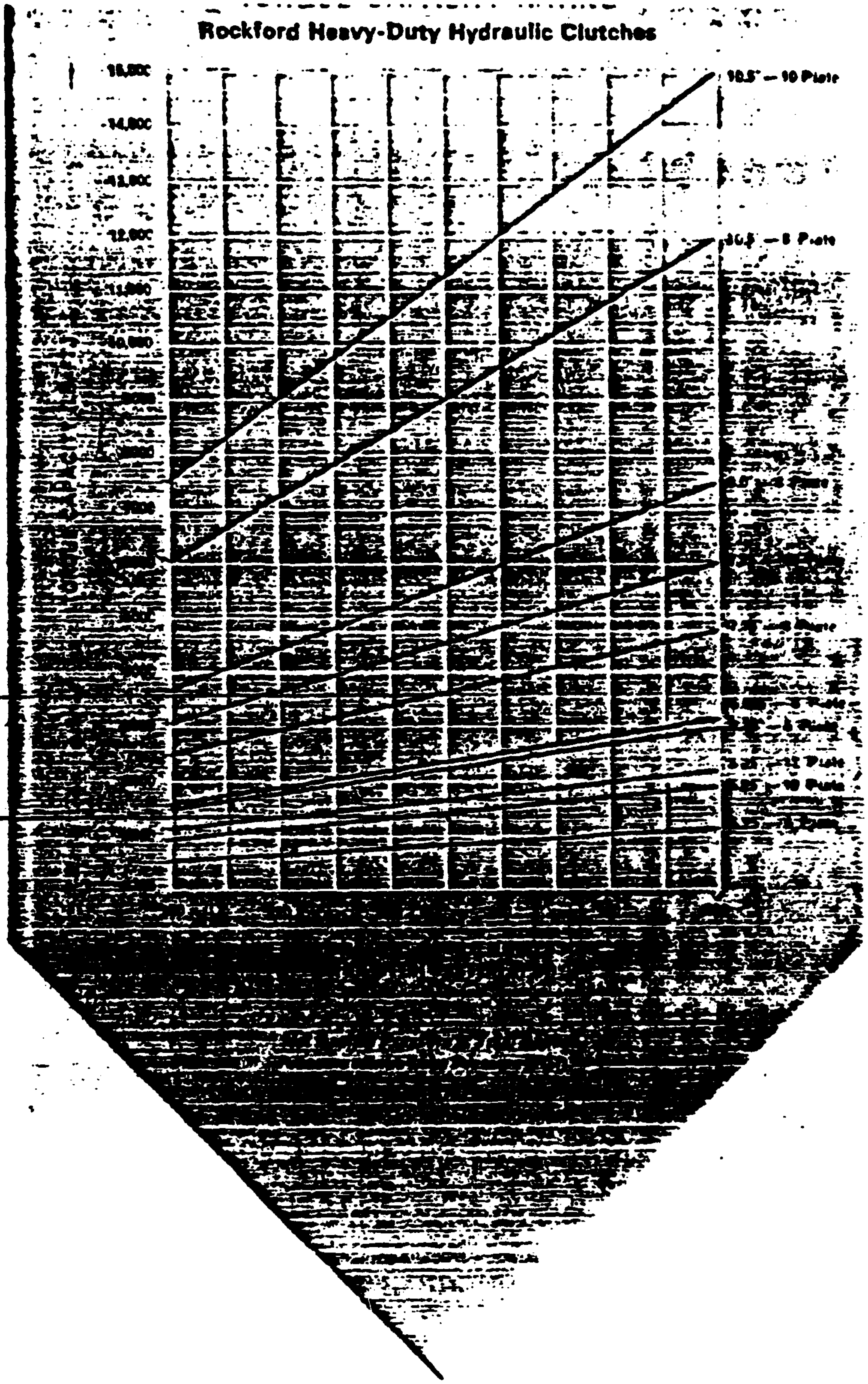
S-N LIFE CURVES

PREPARED FOR REXROTH BY GARY HAMILTON

JOB NUMBER 10007	PINION	GEAR
PART NUMBER	7	8
NUMBER OF TEETH	16	24
DIAMETRAL	6.000	
INPUT TORQUE	5.040	







CLUTCH RATING
@ 150 PSI NET.

7375 LbFT
MAX TORQUE
INTO CLUTCHES

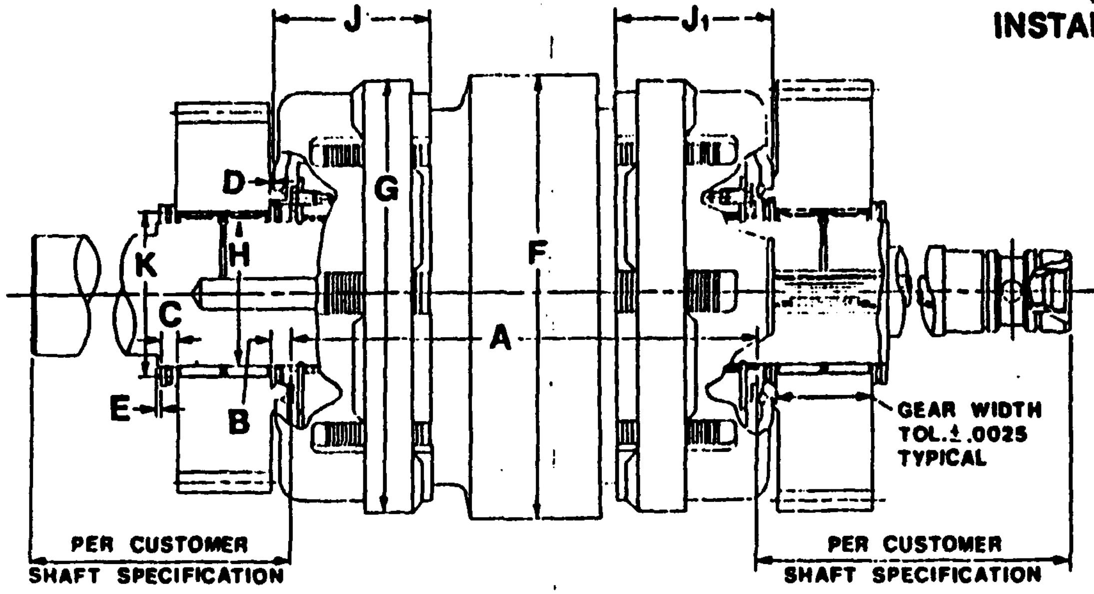
The above chart shows how Clutch Torque Capacity can be varied by increasing the Applied Oil Pressure and/or the number and Diameter of Plates in the Clutch.

This allows the designer great versatility in fitting the Rockford Division into a particular application. Consult our engineering staff for complete details to meet your needs.

Appendix 7

6.625 7.7[illegible] 9.00 & 10.50
Dou[illegible] Pack

6.625, 7.75, 9:00 & 10.50 INSTALLATION DIMENSIONS



6.625 DOUBLE PACK

Plate Qty.	A	B	C	D	E	F	G	H	J	J1	K
8x8	8.90	.1579 .1621	.2619 .2681	.08	.008 .040	7.98	7.78	2.2495 2.2500	2.82	2.82	2.8254 2.8281

7.75 DOUBLE PACK

Plate Qty.	A	B	C	D	E	F	G	H	J	J1	K
5x5	6.70	.1579 .1621	.2619 .2681	.05	.018 .040	9.12	8.90	2.9995 3.0000	2.25	2.25	3.3755 3.3784
8x8 7x7 8x8	8.90	.1579 .1621	.2619 .2681	.08	.008 .040	9.12	8.90	2.2495 2.2500	2.82	2.82	2.8254 2.8281
7x5	7.07	[illegible] .1621	.2619 .2681	.05	.018 .040	9.12	8.90	2.9995 3.0000	2.82	2.25	3.3755 3.3784
8x8 9x9 10x10	9.70	.1579 .1621	.2619 .2681	.08	.018 .040	9.12	8.90	2.4995 2.5000	3.20	3.20	2.8754 2.8781
8x8 [illegible] 10x10	9.70	.1579 .1621	.2619 .2681	.08	.018 .040	9.12	8.90	2.9995 3.0000	3.20	3.20	3.3755 3.3784

9.00 DOUBLE PACK

Plate Qty	A	B	C	D	E	F	G	H	J	J1	K
8x8	9.86	.3699 .3701	.3239 .3301	.05	.006 .040	10.80	10.24	2.9995 3.0000	3.30	3.30	3.3755 3.3784
10x10	10.75	.3699 .3701	.3239 .3301	.05	.006 .042	10.80	10.24	2.9995 3.0000	3.70	3.70	3.3755 3.3784

10.5 DOUBLE PACK

Plate Qty	A	B	C	D	E	F	G	H	J	J1	K
8x8	9.80	.5480 .5827	.9822 [illegible]	.226	.006 .040	12.30	11.78	3.4994 3.5000	3.30	3.30	4.0005 4.0014
10x10	10.90	.5480 .5827	.1422 [illegible]	.226	[illegible] .040	12.30	11.78	3.4994 3.5000	3.80	3.80	4.0005 4.0014

BORG WARNER

Rockford Division

(Formerly Rockford Clutch & Mechanics Divisions)

Borg Warner Corporation
[illegible] Windsor Road, Rockford, Illinois 61101
Telephone 815/633-7460

European Office A. G. Building
[illegible] Champ de Mars, 5, B-1050 Brussels, Belgium
Telephone [illegible] 513 68 10, Telex 23563

Form No. 284[illegible]

Appendix 8

Unit Code: 1 – Feet, 2 – Feet (sq), 3 – Feet (cu), 4 – Gal on, 5 – Pounds, 7 – Ton
(UC)

Component List

Sheet

Item	Description	Finish Size/Model Nº	Material	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part Nº	U C	Suppl. Qty.	Stock	G I	G II	G P
1.0	Axial Piston Pump	AA4V40HD		1.0		1									
2.0	Axial Piston Motor	AA2FM16		2.0		1									
3.0	Control Valve Assy.	AGA-1509-0-C		3.0		1									
4.0	Normally Closed Temp. Switch			4.0		2									

Ind.	X	Date	Name	Change Nº	Remarks

Name
Date
Chk't
Norm

REXROTH USA

Sheet Nº of Sheets

Description: M113 - HYDROSTATIC FAN DRIVE

Parts Code: HS-43-A53-0065-A-0

Part Nº

Supersedes

Superseded by

Punched and Chk'd

PU-A

CRC-O 9-81 772550

Appendix 9

Unit Code: 2-Feet (UC) 3-Feet (sq) 4-Feet (cu) 5-Gal on 6-Pounds 7-Ton

Component List

Sheet

Item	Description	Finish Size/Model Nº	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part Nº	U C	Suppl. Qty.	Stock	G I	G II	G III
1.0	Tandem Gear Pump (14.5 lbs)	1PF2G2-4X/004RN12KDL	1.0		1									
2.0	Gear Pump (9.6 lbs)	1PF2G2-4X/022R12KR	2.0		1									
3.0	Manifold Assy. (275)	AGA-XXXX-X-X-0	3.0		1									
3.1	Filter (Bypass w/elect.warn. on Pr. Differential) 20 GPM. 1500 psi (manifold mnt)	DFBN/HC160P10D1.0/BYPL24	3.1		1									
3.2	Pressure Unloading Valve (normally closed) Size 10 (manifold mnt)	DBW10A-2-3X/100UG24NZ4	3.2		1									
3.3	Check Valve, Size 10, 7psi to close (manifold cartridge)	M-SR10KE021X/5	3.3		2									

Ind.	X	Date	Name	Change Nº	Remarks

Name

Date | Chk't | Norm

Sheet Nº of Sheets

REXROTH USA

Description: M113 - AUXILIARY HYDRAULIC SYSTEM

Parts Code: HS-43-A53-0061-C-1

Part Nº

Supersedes

Superseded by

Punched and Chk'd

PU-A

CDC-B 0-01 77350-

Unit Code: 2-Feet
(UC) 3-Feet (m)
Feet (cu)
Gal on
-Pounds
7-Ton

Component List

Sheet

Item	Description	Finish Size/Model №	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part №	U C	Suppl. Qty.	Stock	G I	G II	G III
3.4	Brake Release Valve, 2 pos.	3WE6AA5X/AG24NZA	3.4		1									
	3-way A-T Normal, Size 6,													
	max. Override (manifold mnt)													
3.5	1/4" In-Line Shut-off Valve	(Vender Item)	3.5		1									
	3000 psi													
3.6	Accumulator (1 Qt.), 1500psi	(Vender Item)	3.6		1									
3.7	Pressure Switch, Normally	HED4)P1X/50214S	3.7		1									
	Closed, Open @ (350) psi													
	(manifold mnt)													
3.8	3 Pos.,4-Way Directional	4WE6J5X/AG24NZ4/5	3.8		1									
	Valve (manifold mnt)													
3.9	Check Valve, 25 psi to open	MS-R10KE151X/5	3.9		1									
	Size - 10 (manifold cartridge)													

Ind.	X	Date	Name	Change №	Remarks

Name
Date
Chk'd
Norm

REXROTH USA

Sheet
№
of
Sheets

Description
M113 - AUXILIARY HYDRAULIC SYSTEM

Parts Code HS-43-A53-0061-C-1

Part №

Supersedes

Superseded by

Punched and Chk'd

PU-A

CMC-B 9-81 77389

Unit Code: 2-Foot
!UC! 3-Foot(sq)
Foot(cu)
Gal on
-Pounds
7-Ton

Component List
Sheet

Item	Description	Finish Size/Model Nº	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part Nº	U C	Suppl. Qty.	Stock	G I	G II	G III
3.10	Pressure Relief Valve,		3.10		1									
	Size 6, 1500 psi (manifold	DBDS6K1x/100												
	cartridge)													
3.11	Filter, 25 GPM, 10 um,	DFBN/HC160P10D1.0/BYPL24	3.11		1									
	Bypass, Elec. Clog Indicator													
	(manifold cartridge)													
3.13	Pressure Reducing Valve,	DR10DP2-3X/25YM	3.13		1									
	Size 10 (manifold cartridge)													
3.14	Filter, 15 GPM, 10 um,	DFBN/HC160P10D1.0/BYPL24	3.14		1									
	Bypass, Elec. Clog Indicator													
	(manifold mount)													
3.15	Check Valve, 25 psi. Size 16	MS-R15KE0151X/5	3.15		1									
	(manifold cartridge)													

Ind.	X	Date	Name	Change Nº	Remarks				
						Name		Description: M113 - AUXILIARY HYDRAULIC SYSTEM	Punched and Chk'd
						Date	Sheet	Parts Code HS-43-A53-0061-C-1	PU-A
						Chk't	Nº	Part Nº	
						Norm	of	Supersedes	Superseded by
						REXROTH USA	Sheets		

CDC-Ø 9-81 77250-

Unit Code: 2-Foot
(UC) 3-Foot (sq)
4-Foot (cu)
5-Gal on
6-Pounds
7-Ton

Component List

Sheet

Item	Description	Finish Size/Model Nº	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part Nº	U C	Suppl. Qty.	Stock	G I	G II	G III
4.0	Flow Limiter, One-Way Free	DRV611/12M	4.0		1									
	Flow													
5.0	Heat Exchanger, 3/4" Finned	(Vender Item	5.0		1									
6.0	Inlet Strainer (100 mesh)	(Vender Item)	6.0		2									
7.0	Hand Pump	(Vender Item)	7.0		1									

Ind.	X	Date	Name	Change Nº	Remarks

Name
Date
Chk't
Norm
Sheet
Nº
of
Sheets

REXROTH USA

Description: M113 - AUXILIARY HYDRAULIC SYSTEM

Parts Code: HS-43-A53-0061-C-1

Part Nº

Supersedes

Superseded by

Punched and Chk'd

PU-A

CDC-D 9-81 77359

Unit Code: 2–Feet (UC) 3–Feet (sq) Feet (cu) Gal on Pounds 7–Ton

Component List

Sheet

Item	Description	Finish Size/Model Nº	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part Nº	U C	Suppl. Qty.	Stock	G I	G II	G III
1.0	Tandem Gear Pump (14.5 lbs)	1PF2G2-4X/004RN12KDL	1.0		1									
2.0	Gear Pump (9.6 lbs)	1PF2G2-4X/022R12KR	2.0		1									
3.0	Manifold Assy. (275)	AGA-XXXX-X-X-0	3.0		1									
3.1	Filter (Bypass w/elect.warn. on Pr. Differential) 20 GPM. 1500 psi (manifold mnt)	DFBN/HC160P10D1.0/BYPL24	3.1		1									
3.2	Pressure Unloading Valve (normally closed) Size 10 (manifold mnt)	DBW10A-2-3X/100UG24NZ4	3.2		1									
3.3	Check Valve, Size 10, 7psi to close (manifold cartridge)	M-SR10KE021X/5	3.3		2									

Ind.	X	Date	Name	Change Nº	Remarks

Name

Date

Chk't

Norm

Sheet Nº of Sheets

REXROTH USA

Description: M113 - AUXILIARY HYDRAULIC SYSTEM

Parts Code: HS-43-A53-0061-C-1

Part Nº

Supersedes

Superseded by

Punched and Chk'd

PU-A

CDC-D 9-81 77380

Unit Code: 2-Feet (UC) 3-Feet(in) Feet(cu) Gal on -Pounds 7-Ton

Component List
Sheet

Item	Description	Finish Size / Model №	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part №	U C	Suppl. Qty.	Stock	I	II	III
3.4	Brake Release Valve, 2 pos.	3WE6AA5X/AG24NZA	3.4		1									
	3-way A-T Normal, Size 6,													
	max. Override (manifold mnt)													
3.5	1/4" In-Line Shut-off Valve	(Vender Item)	3.5		1									
	3000 psi													
3.6	Accumulator (1 Qt.), 1500psi	(Vender Item)	3.6		1									
3.7	Pressure Switch, Normally	HED4)P1X/50214S	3.7		1									
	Closed, Open @ (350) psi													
	(manifold mnt)													
3.8	3 Pos.,4-Way Directional	4WE6J5X/AG24NZ4/5	3.8		1									
	Valve (manifold mnt)													
3.9	Check Valve, 25 psi to open	MS-R10KE151X/5	3.9		1									
	Size - 10 (manifold cartridge)													

Ind.	X	Date	Name	Change №	Remarks

Name
Date
Chk'd
Norm
REXROTH USA
Sheet № of Sheets

Description: M113 - AUXILIARY HYDRAULIC SYSTEM
Parts Code: HS-43-A53-0061-C-1
Part №
Supersedes
Superseded by
Punched and Chk'd
PU-A

CDC-8 9-81 77850

Unit Code: 2-Feet (UC) 3-Feet(sq) Feet(cu) Gallon Pounds 7-Ton

Component List
Sheet

Item	Description	Finish Size/Model №	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part №	U C	Suppl. Qty.	Stock	G I	G II	G III
3.10	Pressure Relief Valve,		3.10		1									
	Size 6, 1500 psi (manifold	DBDS6K1x/100												
	cartridge)													
3.11	Filter, 25 GPM, 10 um,	DFBN/HC160P10D1.0/BYPL24	3.11		1									
	Bypass, Elec. Clog Indicator													
	(manifold cartridge)													
3.13	Pressure Reducing Valve,	DR10DP2-3X/25YM	3.13		1									
	Size 10 (manifold cartridge)													
3.14	Filter, 15 GPM, 10 um,	DFBN/HC160P10D1.0/BYPL24	3.14		1									
	Bypass, Elec. Clog Indicator													
	(manifold mount)													
3.15	Check Valve, 25 psi. Size 16	MS-R15KE0151X/5	3.15		1									
	(manifold cartridge)													

Ind.	X	Date	Name	Change №	Remarks

Name
Date
Chk't
Norm

REXROTH USA

Sheet № of Sheets

Description: M113 - AUXILIARY HYDRAULIC SYSTEM

Parts Code HS-43-A53-0061-C-1

Part №

Supersedes

Superseded by

Punched and Chk'd

PU-A

CDC-D 9-81 77880

Unit Code: 2-Feet
(UC) Feet(sq) Feet(cu) Gal on Pounds 7-Ton

Component List
Sheet

Item	Description	Finish Size / Model Nº	Techn. Pos	D S	Qty. Each	KT	Item of Order	Part Nº	U C	Suppl. Qty.	Stock	G I	G II	G III
4.0	Flow Limiter, One-Way Free	DRV611/12M	4.0		1									
	Flow													
5.0	Heat Exchanger, 3/4" Finned	(Vender Item	5.0		1									
6.0	Inlet Strainer (100 mesh)	(Vender Item)	6.0		2									
7.0	Hand Pump	(Vender Item)	7.0		1									

Ind.	X	Date	Name	Change Nº	Remarks

Name
Date
Chk't
Norm
REXROTH USA
Sheet Nº of Sheets

Description: M113 - AUXILIARY HYDRAULIC SYSTEM
Parts Code: HS-43-A53-0061-C-1
Part Nº
Supersedes
Superseded by
Punched and Chk'd
PU-A

CRC-B 9-81 77250

Appendix 10

Appendix 11

M113
HDSR

INSTALLED WEIGHT

- MECHANICAL HARDWARE -

Item #	Description	Quantity	Weight each	Total Wt.
1.	Pump Drive Box	1 pc.	330 lbs	330 lbs
2.	Engine Bell Housing	1 pc.	18 lbs	18 lbs
3.	Modified Mtg. Brackets	2 pcs.	10 lbs	+10 lbs
4.	Final Drives	2 pcs.	390 lbs	780 lbs
5	Fin. Dr. & P.Dr. Hardware	--	20 lbs.	20 lbs.
6.	Accelerator Pedal	1 pc.	5 lbs.	5 lbs.
7.	Brake Pedal	1 pc.	5 lbs.	5 lbs.
8.	Steering Assembly	1 set	30 lbs.	30 lbs.

- ELECTRONIC HARDWARE -

* Does not include Data Acquisition System

1.	Voltage Stabilizer	1 pc.	1 lb.	1 lb.
2.	Electronics (cards)	5 pcs.	1 lb.	5 lbs.
3.	Enclosure	1 pc.	15 lbs.	15 lbs.
4.	Wiring/connectors(MIL-C-5015)	1 set	8 lbs.	8 lbs.
5	Mounting Hardware	1 set	4 lbs.	4 lbs.

- HYDRAULIC HARDWARE -

Dwg. HS-43-A53-0056-0-4

1.	Item 1.0, Pump	1 pc.	287 lbs.	287 lbs.
2.	Item 2.0, Motors	4 pcs.	154 lbs.	616 lbs.
3.	Item 3.0 Manifold Assy.	1 pc.	32 lbs.	32 lbs.
4.	Item 4.0 Check Valve	1 pc.	84 lbs.	84 lbs.
5.	Item 5.0 H.P. Accumulator	1 pc.	100 lbs.	100 lbs.
6.	Item 6.0 L.P. Accumulator	1 pc.	50 lbs.	50 lbs.
7.	Item 7.0 M.D. Accumulator	2 pcs.	10 lbs.	20 lbs
8.	Item 8.0 Filter Assy.	1 pc.	19 lbs.	19 lbs.
9.	Item 9.0 Heat Exchanger	1 pc.	84 lbs.	84 lbs.
10.	Item 13.0 Reservoir Assy.	1 pc.	170 lbs.	170 lbs.
11.	-------- Mounting Hardware		20 lbs.	20 lbs.
12.	Plumbing/fitting	-	200 lbs.	200 lbs.
13.	Hydraulic Fluid (45 Gals)		300 lbs.	300 lbs.

Dwg. HS-43-A53-0062-C-0

1.	Item 1.0 Pump	1 pc.	64 lbs.	64 lbs.
2.	Item 2.0 Mctor	1 pc.	12 lbs.	12 lbs.
3.	Item 3.0 Manifold	1 pc.	25 lbs.	25 lbs.
4.	Item 4.0 Filter Assy.	1 pc.	14 lbs.	14 lbs.
5.	Mounting Hardware	1 set	10 lbs.	10 lbs.
6.	Plumbing/fittings	1 set	40 lbs.	40 lbs.

Dwg. HS-43-A53-0061-C-1

1.	Item 1.0 Pump	1 pc.	8 lbs.	8 lbs.
2.	Item 2.0 Pump	1 pc.	9 lbs.	9 lbs.
3.	Item 3.0 Manifold Assy.		270 lbs.	270 lbs.
4.	Item 4.0 Valve	1 pc.	8 lbs.	8 lbs.
5.	Item 5.0 Heat Exchanger	1 pc.	10 lbs.	10 lbs.
6.	Item 7.0 Hand Pump	1 pc.	10 lbs.	10 lbs.
7.	Mounting Hardware	1 set	25 lbs.	25 lbs.
8.	Plumbing/Fittings	1 set	80 lbs.	80 lbs.
9.	System Fluid 20 Gals.		180 lbs.	180 lbs.

EST. TOTAL INSTALLED WEIGHT = 3958 lbs.

Appendix 12

ATTACHMENT 12

1.0

Logic in the HDSR control circuit is designed to be automotive in nature. With this system, an operator will be able to drive and control vehicle functions in much the same manner as is required to drive and control an automobile with a semi-automatic transmission (or fully automatic) and with power assist in steering and braking. Operator feedback with this system is mainly visual as explained in Par. 5 (page 20) of the report text.

1.1

Control circuits fall into four (4) main categories:

- Acceleration and speed control
- Braking
- Direction Control
- Steering

1.1.1

There is an optional engine speed control to maintain engine speed within ± 5% of optimum for given HP requirements.

1.1.2

Refer to the attached control circuit diagram when reviewing the following:

1.2 Acceleration and Speed Control

1.2.1

Acceleration and speed are controlled by setting motor displacements at volumes which are keyed to vehicle speed and/or acceleration requirements.

1.2.2

The operator controls speed/acceleration with a foot pedal which transmits a voltage signal to the circuit by means of a potentiometer. The foot pedal/potentiometer system which was furnished with the vehicle will be used to accomplish this function.

1.2.3

When more vehicle speed is signaled, the voltage signal is routed through a current amplifier which signals motor proportional control valves to provide more control pressure to increase motor displacements. All motors will be stroked simultaneously. Circuit and individual component pre-adjustments will assure accuracy.

1.2.4

This mode of control is open loop torque control with operator sensory perception of speed or acceleration controlling the speed of the vehicle or the rate of change of speed.

1.2.5

When vehicle speed reaches a point at which pump flow is inadequate to reach the speed signaled by the operator, system pressure will begin to drop and a secondary electronic loop overrides the primary loop and motors are destroked to maintain system pressure.

1.2.5.1

This mode of control is torque/speed (HP) limited and the vehicle will continue to accelerate to the desired speed until external loads and/or system considerations limit vehicle top speed.

1.2.6

Equal motor displacement is further assured by closed loop steering control which is further explained in the steering control portion of this report.

1.3 Vehicle Braking

1.3.1

Vehicle braking is accomplished in two modes:

- Dynamic braking
- Emergency and parking

1.3.2

Dynamic braking is accomplished by reversing signal logic used in acceleration/speed control. Signal input for this mode of operation comes from a brake pedal potentiometer which is current amplified to actuate the logic reversing relay. Signal inputs from the brake pedal stroke the motors in the reverse mode and braking energies are directed back into the engine.

1.3.3

Dynamic braking continues proportional to brake pedal pressure until signal level commands that emergency braking is needed. At this point, failsafe brake on the final drive units are energized and the vehicle is stopped.

1.3.4

When the brake pedal is released, all systems are automatically returned to normal forward propulsion modes.

1.3.5

The brake pedal supplied (GFE) with the vehicle will be used to provide braking control loop input.

1.3.6

Additional dynamic braking is achieved as the operator reduces the speed command to the system. Vehicle speed is controllable with the accelerator pedal until the operator removes his foot from the pedal at which point the hydraulic system is in neutral and the brake pedal must be used.

1.4 Vehicle Direction Control

1.4.1

Vehicle direction and/or mode of operation is managed by a control lever on the operator's console. As with an automotive automatic transmission control, this lever signals the following vehicle modes:

- Park (P)
- Reverse (R)
- Neutral (N)
- First Gear (1)
- Second Gear (2)

1.4.1.1

In the Park (P) position, the HDSR system is in neutral and the parking brake is set. In this mode, there is no flow or pressure in the HDSR system.

1.4.1.2

In the Reverse (R) position, vehicle operation is the same as is described in forward operation (Par. 1.2) except vehicle direction is reversed. In this mode, gear change options are limited to first (1) gear only.

1.4.1.3

In the Neutral (N) position, the parking brake is released, the pump DA control is actuated with HDSR system flow and pressure established. In this mode all systems are on standby and ready for forward or reverse operation. The vehicle may be towed in this mode.

1.4.1.4

With the vehicle control lever in the First (1) gear position, vehicle forward operation is as described in par. 1.2. Gear change options in this mode is limited to first (1) gear.

1.4.1.5

With the vehicle control lever in the Second (2) gear position, gear change options may be limited to Second (2) gear only or may provide power a shift type control which automatically changes gears from first (1) gear to second (2) gear and vice-versa. It is recommended that initial development of the HDSR transmission limit gear shift options to second (2) gear only in this control position. This leaves gear change options to a manual mode. After the manual mode is proven, power shift options will be added.

1.5 Steering Control

1.5.1

Vehicle steering control logic is accomplished with two control loops:

- Closed loop motor speed control for high-speed steering control.
- Open loop motor displacement (Torque) control for sharp (low-speed) turns.

Transition between the two steering modes is automatic and is determined by the position of the steering (wheel) control.

1.5.2

Speed characteristics of individual track mechanisms obey the following relationships in powered turns:

Vm = Vehicle Speed

Rm = Mean vehicle turn radius

Vr = Right Track Speed = $(Rm-S/2)\omega = (1-S/2Rm)Vm$

Vl = Left Track Speed = $(Rm+S/2)\omega = (1+S/2Rm)Vm$

These equations are used in closed loop (Speed Control) logic. This is control loop No. 1.

1.5.3

The following algorythms are used in (Open loop Torque) control. This is control loop No. 2

$\alpha R = -\alpha$ Gas Pedal $(1-2Rm/S)$

$\alpha L = \alpha$ Gas Pedal $(1+2Rm/S)$

Where S = Track gage.

With this control logic, the transition from control loop No. 1 and control loop No. 2 will be smooth and there will be no reaction of feel or vehicle operation during the transition.

Figures 1 and 2 on the following pages show steering logic graphically.

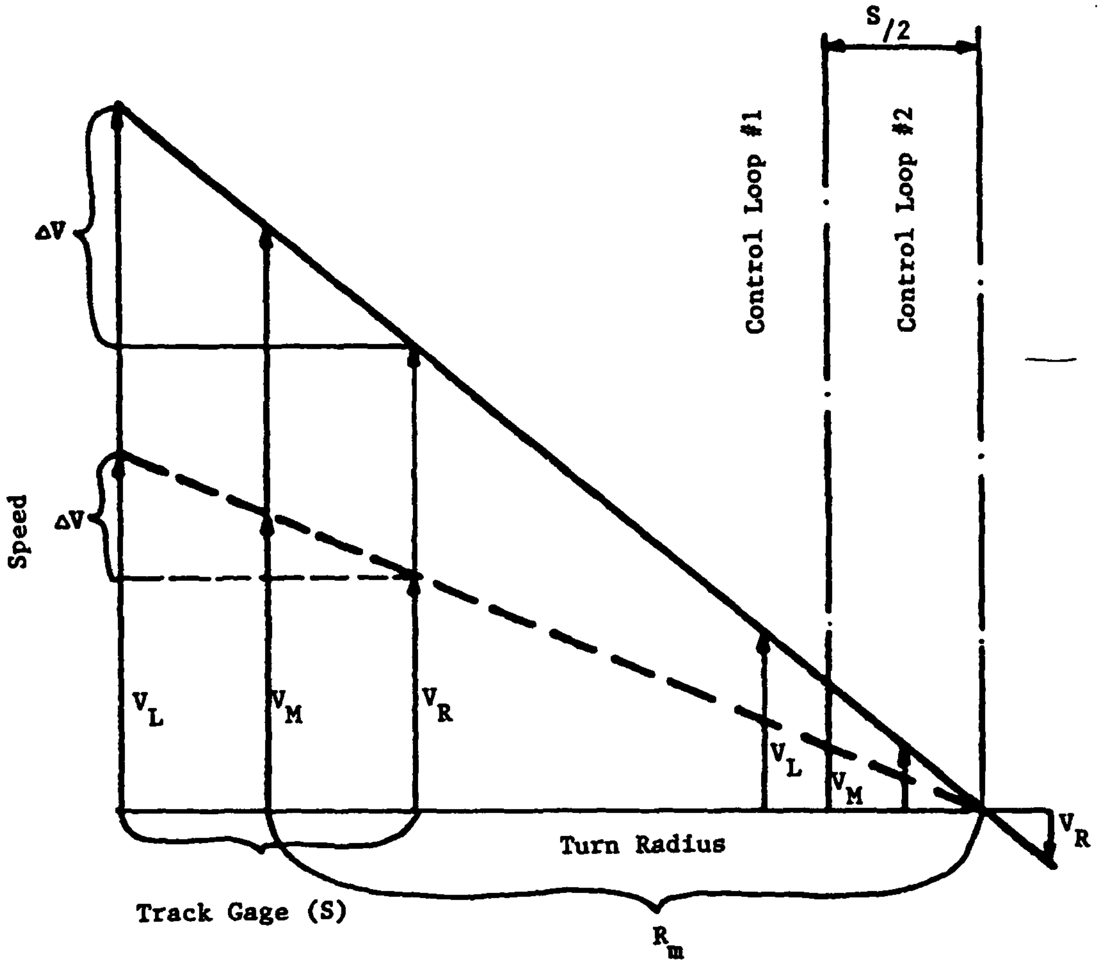
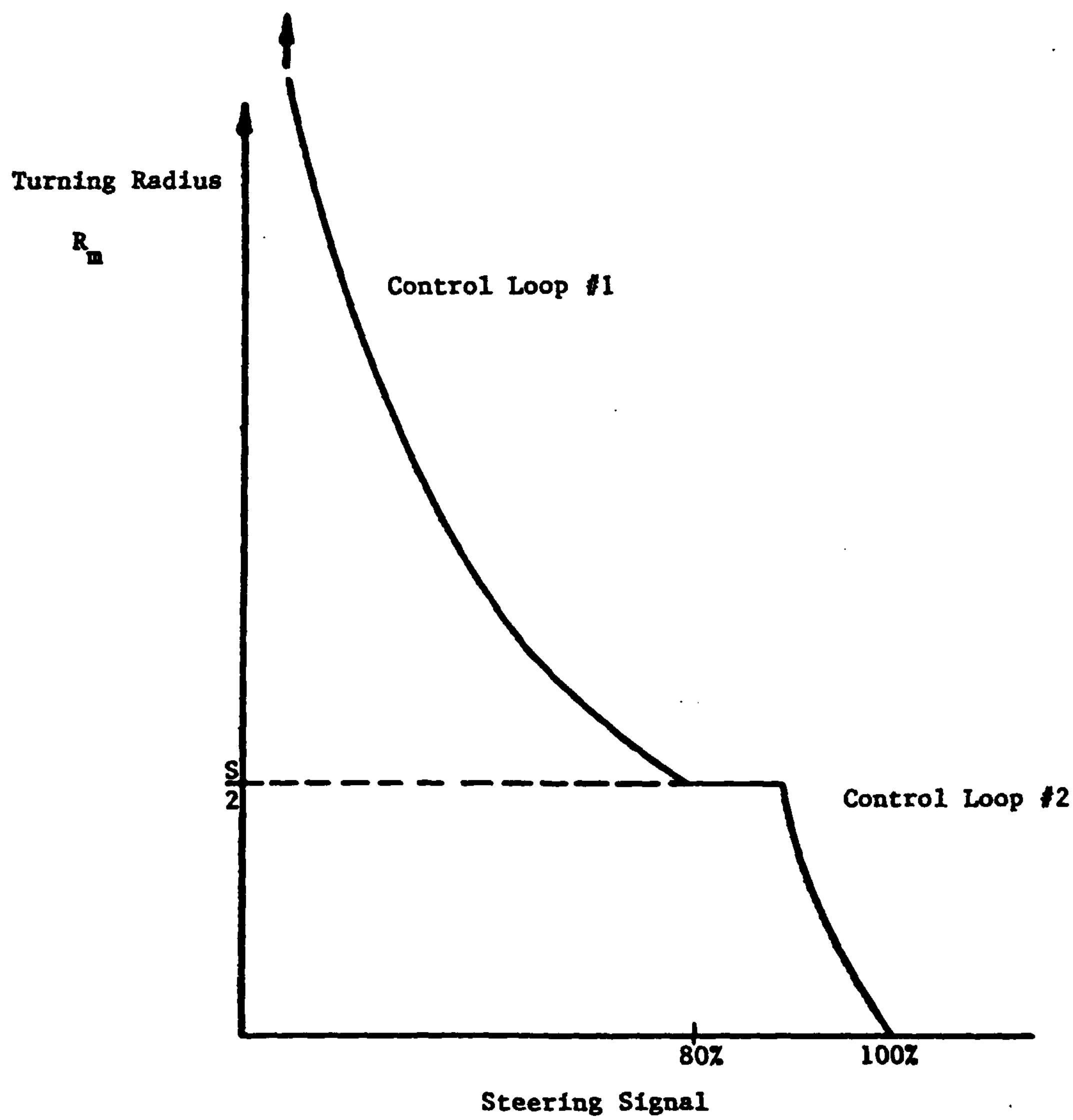

S/2
Control Loop #1
Control Loop #2
ΔV
ΔV
Speed
V_L
V_M
V_R
V_L
V_M
V_R
Turn Radius
Track Gage (S)
R_m

Figure 1



Turning Radius
R_m
Control Loop #1
$\frac{S}{2}$
Control Loop #2
80%
100%
Steering Signal

Figure 2

1.5.4

Closed loop motor speed control (Control Loop No. 1)

1.5.4.1

This steering control is used for most vehicle operations and is signaled for 80% of the steering (wheel) control motion.

1.5.4.2

When the steering (wheel) control is turned a voltage signal is generated across the steering potentiometer. This signal is first compared for control loop No. 1 or No. 2 mode. For control loop No. 1 the signal is then converted to a MA current signal and input to a speed comparison logic element which is also input from the motor tach. generators. Actual motor speed differentials are compared and motor speeds adjusted until speed differential matches the command signal.

1.5.4.3

Steering signals are not linear with position of the steering (wheel) control and will provide fine steering adjustment for nominal steering wheel movements. See Figure 2 on the previous page.

1.5.4.4

This speed control with electronic feedback will also assure straight line vehicle operation when no steering signal is commanded. This is irrespective of external loads.

1.5.5 Open loop motor torque control (Control Loop No. 2)

1.5.5.1

When the steering (wheel) control into the final 20% of control motion, steering loop No. 2 is automatically commanded. Steering control logic will make this transition when the vehicle turn radius is signalled for a turn radius of less than half the track gage. As previously stated, this is the optimum transition point.

1.5.5.2

In control loop No. 2, voltage signals are converted to current signals. Signal logic is as shown on the circuit diagram and in par. 1.5.3.

1.5.5.3

Control loop No. 2 steering control is motor torque control and is used for turn radii of less than half the track gage, including spin (Counter-Rotation) turns.

1.6.0 Other Control Logic

1.6.1

For all vehicle mobile operations, vehicle speed is monitored and input to the main pump DRE control. This, in conjunction with the DBET pressure control, reduces system pressure as vehicle speed increases. It is planned that system pressure be reduced from a maximum of 5800 psi at 3 MPH to a minimum of 2850 psi at 40 MPH. Dynamic testing may prove other pressure setting to be more efficient; final pressure values will be selected during dynamic testing.

1.6.2

In all operating modes, the following system parameters will be measurable and usable for vehicle control systems. (See data acquisition plan)

- Motor displacements, speeds and pressure.
- Pump displacement, speed and pressure.
- Rate of change of any of the above may also be measured.

1.6.2.1

Measuring motors and pump displacements, speeds and pressures and rates of change, essentially measures pump (Engine) HP vs. Motor (Vehicle) HP levels and rates of change.

1.6.2.2

Input of this data into a logic element makes it possible to control engine speed as a function of HP. Engine operation may then be managed to optimize engine performance (Economy).

Optimization of engine speed vs. HP requirements is only possible if engine performance data is provided to define optimum conditions.

1.7.0

Control logic and circuitry will be a continuing development process throughout the program at Rexroth. The proposed system is a flexible system which lends itself to fine tuning and adjusting to obtain desired control features.

1.7.1

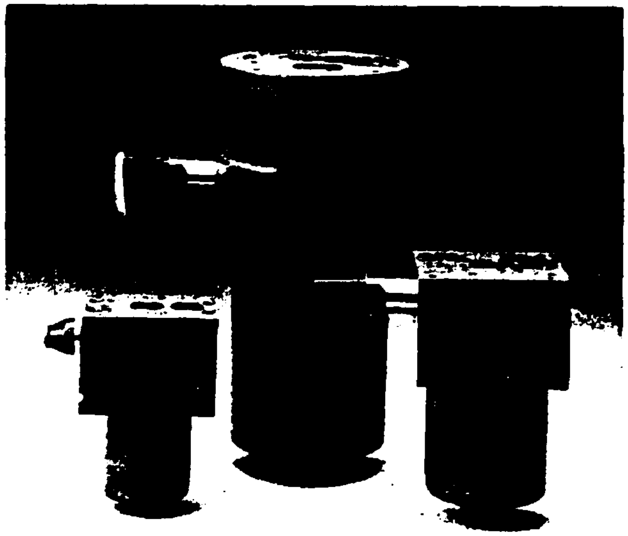
For future programs (production related), all analogue logic and circuitry can be handled by a control digital system if digital logic is fast enough and/or if digital control is desired.

1.7.2

The control module will be housed in a painted steel cabinet which will be 9"x12"x12". It will be located on the shelf which is directly behind the operator.

REXROTH WORLDWIDE HYDRAULICS	Pressure Filters for Manifold Block Mounting			RA 31 300/8.86
	Series DF-P, DF-AP	... 4600 PSI (315 bar)	... 180 GPM (680 L/min)	

- Designed to be mounted directly onto manifold block to save space and reduce leakage points and mounting hardware
- Filter head and screw-in bowl constructed of cold-formed steel (DF 330 P and DF 660 P have a spherical graphite cast iron filter head)
- Filter housings designed to withstand pressure surges as well as high static pressure loads
- Visual, electrical, visual/electrical, or electronic clogging indicators available on inlet/outlet ports on top (DFP) or side (DFAP) of filter head
- Multiple indicator port locations available for maximum flexibility and multiple types of indicators
- Screw-in bowl for easy removal of filter element
- Available with by-pass valve so either high or low collapse pressure elements may be selected



Functional Description

GENERAL
The DFP and DFAP High-Pressure Filters are designed to be mounted directly onto the manifold block to save space and reduce leak points and mounting hardware.

CONSTRUCTION
Most models of DFP and DFAP filters have a steel filter head and a screw-in bowl made of cold-formed steel. The DF 330 P and DF 660 P have a spherical graphite cast iron filter head and a screw-in bowl of cold formed steel. The filter housings are designed to withstand pressure surges as well as high static pressure loads. The screw-in bowl allows the filter element to be easily removed for replacement or cleaning. Basic models DFP and DFAP do not have clogging indicators.

However, a visual, electrical, visual/electrical, or electronic clogging indicator can be installed. DFP and DFAP filters are available with or without a by-pass valve so either high or low collapse pressure elements may be selected.

PRODUCT FEATURES
The DFP has inlet/outlet ports in the top of the filter head, and the DFAP has inlet/outlet ports on the side of the filter head to provide flexibility in mounting the filter to the manifold block.

Multiple indicator port locations can be specified on REXROTH DFP and DFAP filters to best fit the filter clogging indicator into the space available on the manifold block assembly.

Multiple indicator port locations also allow two different types of indicators to be installed into the filter. Indicators with two different trip pressures can also be installed.

FILTER ELEMENTS
The DFP and DFAP filters are available with disposable REXROTH Betamicron® BN and BH elements having 435 PSID and 3000 PSID collapse pressure and absolute ratings of 3, 5, 10 and 20 microns.

For extended element service life, the DFP and DFAP are available with disposable REXROTH Betamicron® BN/HC and BH/HC high-capacity elements having 435 PSID and 3000 PSID collapse pressure respectively and absolute ratings of 3, 5, 10, and 20 microns. These high-capacity elements have more media surface area and lower pressure drop than the standard Betamicron® BN and BH elements.

Cleanable elements are also available for the DFP and DFAP. Metal Fiber 4*plus*4 stainless steel fleece elements have 4500 PSID collapse pressure and nominal ratings of 3, 5, 10 and 20 microns. Wire screen elements have 435 PSI collapse pressure and nominal ratings of 25, 74, and 149 microns.

For non-bypass applications, Betamicron® BH, Betamicron® BH/HC, or Metal Fiber 4*plus*4 elements must be installed.

If a by-pass valve is used, Betamicron® BN, Betamicron® BN/HC, or wire screen elements can be installed.